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ELECTRICAL SECTION.

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Safe and Accurate Electric Safety Fuses.

Their Evolution, Principle, Operation and Application.

BY JOSEPH SACHS, M.A.I.E.E.

EXCESS-CURRENT PROTECTION.

Wherever electrical energy is expended upon a conducting medium heat, mechanical motion or chemical change are resulting manifestations. The conducting medium or apparatus, having a definite working capacity, it becomes necessary to limit the energy impressed upon it, so that the consequent heat, motion or chemical activity shall not exceed the safety limit. Injurious effects due to the excessive heat-development in conductors or the damaging results of sparking at commutating mechanism are dependent upon the rate of transformation. The impressed power and the time of its duration enter as direct functions. Injury from excessive mechanical strains and chemical changes are per-

haps more dependent upon the rate of change from the normal to the abnormal condition as well as upon the amount and duration of the injurious effects.

Two excess current conditions are generally considered: "overload" and "short circuit." These are but extremes of the same abnormal effect, due to either decreased impedance in the entire circuit acted upon by the impressed E.M.F. or to an abnormal rise in E.M.F. Overloads require an appreciable time to affect the apparatus injuriously, whereas, in the case of short circuits, the instantaneous development and large amount of electrical energy thrust upon the circuit almost eliminates any consideration of time as a function in the resulting effect. Great injury also results from a practically instantaneous rupture of an electrical circuit and the consequent momentary rise in potential due to inductive and capacity effects. It is of the utmost importance that the cessation of current flux should not take an instantaneous drop, but should rather slant off, even though the interval for such gradual rupture be exceedingly small. Excess current protective devices should be based upon these considerations. Their overload characteristics should be similar to those of the device protected.

There are two types of safety devices used in practical electrical work — the one is based upon the transformation of electricity into heat energy, and the other on the mechanical energy developed or released by the magnetic effect of the current. The vast multitude of protective devices are of the former type, the latter having found particular application where the matter of cost, mechanical complexity and other obvious deficiencies could be relegated to a secondary consideration, as compared with their advantages. Thermal safety protective devices, or fuses, aside from their mere simplicity have, however, inherent features which are probably the cause of the enormous use to which they have been put.

Three elementary requirements may be given for all practical excess current protective devices, as follows:

(1) Definite, unchangeable maximum continuous running current-carrying capacity.

(2) Definite energy overload capacity, depending inversely on the overload, and adjusted, with the allowance of a reasonable safety factor, to the apparatus protected. Like the apparatus protected, the safety device should be uninjured by a momentary overload of shorter duration than the time interval causing injury. The factor of safety should be less than in the device protected. Its operative principle should cause it to act instantaneously on short circuit and in a time inversely dependent on the amount of ordinary overload.

(3) Safe rupture operation. No device is universally safe unless the arc and explosive effect, coincident with the rupturing of the circuit under any condition for which it is intended, is entirely suppressed or eliminated. It should not only prevent damage to extraneous devices, but should also be non-destructive to all connected parts other than those directly operative.

SAFETY FUSES.

The writer hopes he may take for granted the fact that the shortcomings of the old air-exposed fuse wire or strip, be it of lead-tin or alloy, copper, aluminum or possibly a hairpin, as has frequently been found the case by the electrical inspector, is beset with evils which scarcely require additional notoriety. Electrical engineers have learned that safety and accuracy in devices intended as a safeguard imply more than a mere opening of the circuit and the discontinuance of the current. Experience, in its usual expensive manner, has demonstrated the necessity of eliminating destructive arcing and the many variable factors which are inherent adjuncts in all exposed fuse devices. The elimination of arcing from fuse protective devices has proven a prolific field for the enlargement of the patent office receipts. It may be said, with credit to the majority of inventors of such devices, that a multitude of them have found practical application. Nearly all of these improvements, however, are in the direction of arc blow-out or checking arrangements. Only within the last five years has the very simple arrangement, known as an enclosed fuse, been constructed,

so that the arc, as we know it in the open air, really never exists. As a competing device, with its much cheaper, and perhaps, it may even be said, simpler predecessor, it has had to overcome the prime objection of increased cost; but judging from commercial results, enclosed fuses have unquestionably come to stay, and will eventually supplant the air-exposed devices.

Among the earliest attempts, a favored arrangement to prevent the continuance of destructive arcing and the spat-

FIG. 1.—Edison fuse plug

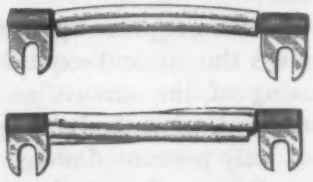


FIG. 3.—Soft rubber tube fuses.

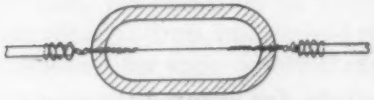


FIG. 2.—Edison enclosed fuse. Patent of May 4, 1880.

FIG. 4.—Fuse in center of close fitting insulating cylinder.

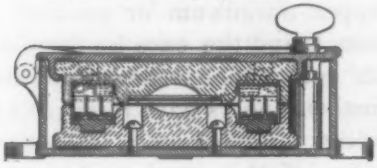


FIG. 5.—Fuse encased between two insulating blocks.

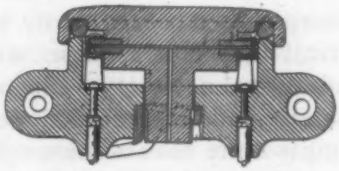


FIG. 6. -Fuse in centrally vented holder.

PLATE A, FIGS. 1–6.—Early enclosed fuses.

tering of molten metal consisted in encasing the fuse conductor in a tube or jacket of some insulating substance, as exemplified in the patent to Edison, May, 1880. Such mere jacketing under severe conditions of excess-current rupture results either in the sudden and forcible expulsion of flaming metallic vapors at the ends of the tube or casing if open, or, as in the case of the well-known Edison plug, or similarly arranged encased fuses, in the bursting or burning of the metallic cap, and frequently in the destruction of the entire

device. Glass, fiber or other insulating casings surrounding the fuse strip, and enclosing an appreciable amount of air, are arrangements which have found continued favor (see *Figs. 1, 2, 3, 4, 5, 6*). The results of rupture are shown in *Figs. 7, 8, 9, 10.*

The present enclosed fuse consists of an insulating tube encasing the fuse strip and a so-called filling material. The

FIG. 7.—Air-filled, 500 volts.

FIG. 8.—Solid wood cylinder.

FIG. 9.—Solid wrapped asbestos.

FIG. 10.—Air-filled, 220 volts.

PLATE B.—Rupture results air-filled and solid case fuses.

latter is usually a finely divided insulating powder, and occupies all, or the larger part of the space within the tube. Its function is to prevent the formation and maintenance of any arc upon rupture of the wire, and also to fix the several variable factors affecting the carrying capacity and melting of the strip. The ends are closed with caps or ferrules which act as circuit terminals, or from which the circuit terminals

project, and the combination thus forms a self-contained composite fuse structure. Some years ago the mechanical arrangement of the filling about the fuse wire received a great deal of attention. Some manufacturers deemed it essential to place it so as to leave a portion of the wire, preferably a short length, at the center, surrounded by an air space (see *Figs. 11, 12, 13*). Later product, however, shows that the air space has been dispensed with, and at the present time it may be stated that the great majority of enclosed fuse devices simply have a powder completely surrounding

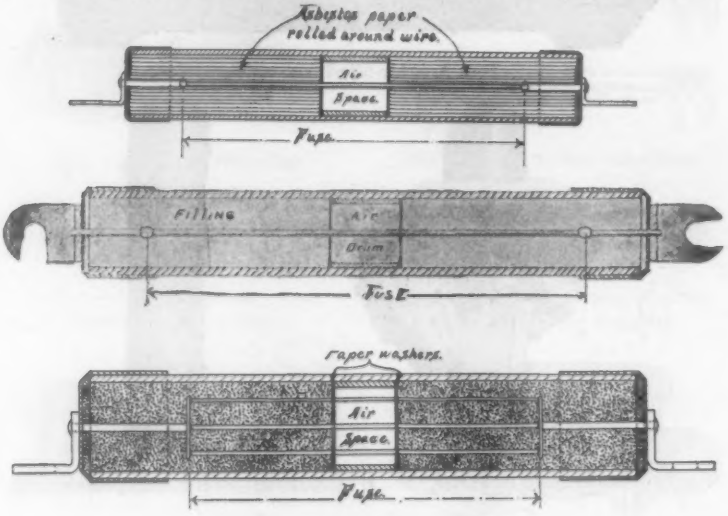


PLATE C, FIGS. 11, 12, 13.—Air-space fuses.

the wire, filling the entire space within the tube. The writer, in a paper presented before the A.I.E.E., entitled "The Evolution of Safe and Accurate Fuse Protective Devices," endeavored to show that the air space was not essential to an enclosed fuse, and maintained the superiority of a solid-packed or solid-filled type. This position seems to have been correct, for, except in small capacities and for delicate fuses, the solid filled arrangement will probably become the standard enclosed fuse structure (see *Figs. 14, 15, 16, 17*).

In the following analysis of the principles and essential

elements of enclosed fuse devices, it is intended to show the desirable qualifications which devices of this character should possess, and not so much lay down all the necessary laws and formulæ for their production and manufacture. In view of the almost universal development and adoption

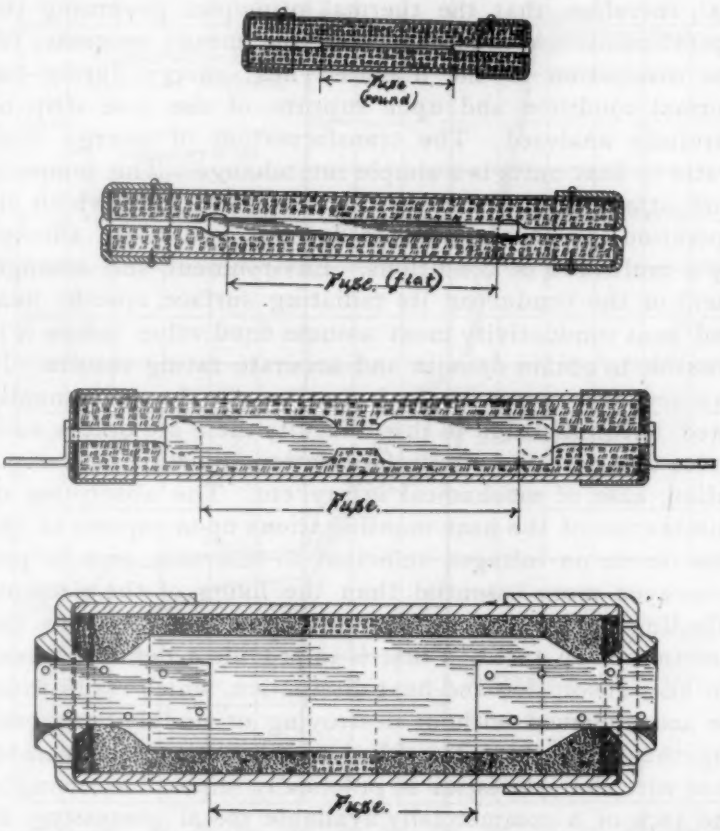


PLATE D, FIGS. 14, 15, 16, 17.—Sach's solid filled fuses (interior arrangement).

of enclosed fuse protective devices, a proper conception of the various principles which must be taken into consideration will be of interest to the users of such devices as well as to the manufacturer, to whom they are probably already known.

GENERAL PRINCIPLES AND EVOLUTION OF THE ESSENTIAL ELEMENTS OF ENCLOSED FUSES.

Two essentials require consideration: The heat-generating strip and the heat-dissipating environment, the latter including filling material, tube, terminals, etc. It is essential, therefore, that the thermal principles governing the operation of fuse conductors and the means necessary for the dissipation of the liberated heat energy during the normal condition and upon rupture of the fuse strip be carefully analyzed. The transformation of energy from watts to heat units is a simple interchange. The temperature attained, however, by the strip, and upon which its operation as a fuse conductor depends, is a result affected by a multitude of conditions. Environment and arrangement of the conductor, its radiating surface, specific heat and heat conductivity must assume fixed value before it is possible to obtain definite and accurate rating results. In exposed fuse wires these factors cannot be permanently fixed, but in addition to this difficulty there are others, such as the deteriorating effect of oxidation, difficulty of manipulation, ease of mechanical injury, etc. The absorption or elimination of the heat manifestations upon rupture of the fuse device on voltages sufficient to maintain arcs is perhaps even more essential than the fixing of the elements affecting accuracy of rating. Briefly stated, therefore, the function of an enclosed fuse is to provide a definite means for heat absorption and heat dissipation, which result must be accomplished without destroying or unduly deteriorating the external parts. Ideal adjustment of the various fuse-wire characteristics is practically impossible, owing to the lack of a commercially available metal possessing all the necessary qualifications. A careful consideration of the following characteristics of the metal selected as a fuse conductor is essential to obtain the best results.

So far as its carrying-capacity features under normal running conditions prior to rupture are concerned, the conductor should be of high electrical conductivity. The potential drop is thus reduced to a minimum, and the conse-

quent smaller section and mass require less energy to effect the temperature.

A low melting point is desirable, because the heat produced in the fuse strip is transmitted by conduction to all

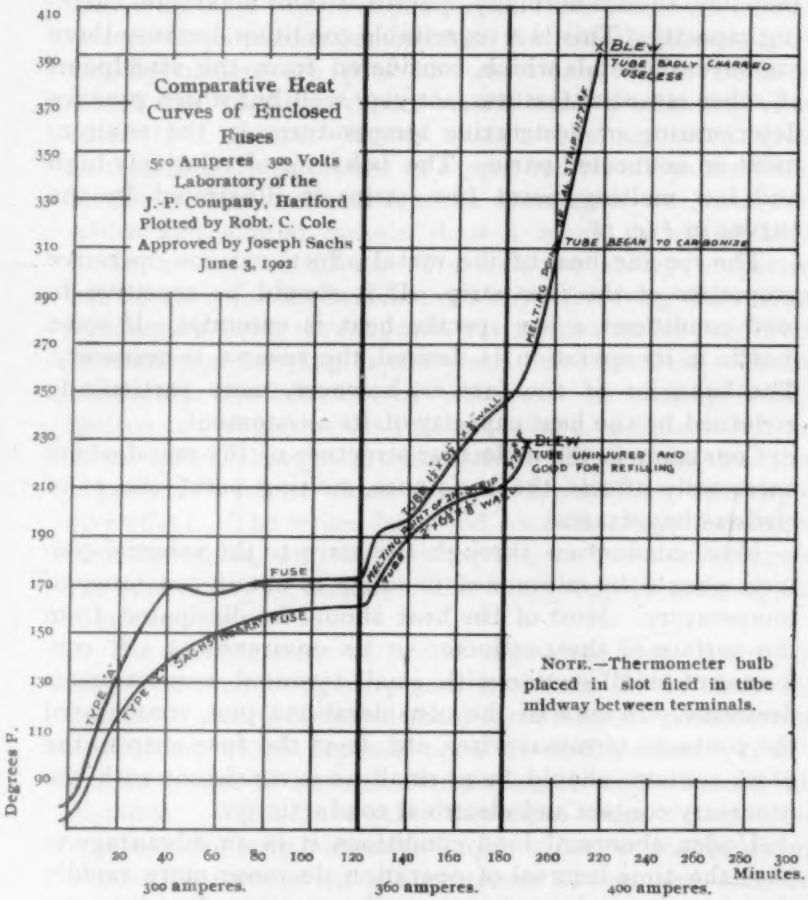


PLATE E, FIG. 18.—**Relative heating of enclosed fuses.**

connected parts, heating them correspondingly. For obvious reasons the operative temperature of the terminals holding contacts, tubular casing, etc., should be reduced to a minimum.

Most metals, if of good conductivity, are usually of high melting point. The fuse conductor should preferably have a melting temperature as much below red heat as is consistent with good conductivity. Conductors whose melting point exceeds 1000° F. are scarcely desirable if it is intended that they should normally operate at their maximum carrying capacity. This is a regrettable condition, because there are several metals which, considered from the standpoint of other essential features, act very well, but which produce deteriorating or destructive temperatures in the environment or connected parts. The behavior of relatively high and low melting-point fuse strips is illustrated by the curves in *Fig. 18.*

The specific heat of the metal affects various operative properties of the fuse strip. If it should be sensitive to load conditions, a low specific heat is essential. If some inertia in its operation is desired, the reverse is necessary. The behavior of the fuse is, however, more particularly governed by the heat capacity of its enviroment.

Constancy in the molecular structure of the metal which necessarily affects the resistance, melting point, etc., is of obvious importance.

Heat conduction through the strip to the external contacts should be minimized in order to obtain constancy of temperature. Most of the heat should be dissipated from the surface of the conductor to its environment. A conductor of small section with small terminal connections is desirable. In view of the considerations just enumerated the contacts, terminal wires, etc., from the fuse strip to the block contacts should be as small as is consistent with the necessary contact and electrical conductivity.

Under abnormal load conditions it is an advantage to have the time interval of operation decrease more rapidly than in a direct inverse ratio to the current. For this reason a fuse strip made of a metal having a large temperature co efficient will show the best results.

Under rupture conditions it is primarily essential that the strip should pass from normal to zero conductivity, with the minimum heat demonstration and arcing. Some

metals, when vaporized, have what might be called arc-sustaining properties, while others sustain the arc with difficulty. With the former the arc may be maintained to a much greater distance between the electrodes than with the latter. It would appear that the arc-sustaining properties of metallic vapors depend upon their electrical conductivity. Experiments demonstrate that metals whose vapors rapidly oxidize are poor arc sustainers, while those in which the metallic vapors retain their conducting character to a greater degree sustain the arc with great vehemence. Such metals as copper and its alloys are undesirable as fuse conductors, while aluminum, zinc, lead, cadmium and similar metals show a much better behavior under arcing conditions. The relative arcing properties can be very quickly demonstrated by subjecting the various conductors to be investigated to rupture under conditions of maximum carrying capacity and fixed overload. In this connection the behavior of the metal in passing from a molten to a vaporous condition may also be considered. A metal which changes gradually from one state to the other is preferable to one which changes its condition with explosive effect. The writer has used lead-tin alloy, aluminum, zinc, cadmium, tin, etc., but experience has demonstrated the superiority of metals of the zinc group in meeting the requirements.

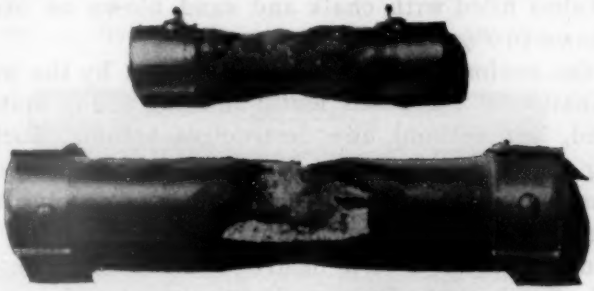
The maintenance of arc is also dependent upon the length of conducting strip used as a fuse. Every metal has a definite arcing distance, under certain fixed excess-current conditions, which depends upon its environment. It is a simple matter to have the strip's length amply exceed this distance. While it would, therefore, seem desirable to lengthen the strip, excessive length is impracticable, owing to size limitations in the complete device, and also because excessive length in the fuse strip results in correspondingly greater heat developed and a larger essential E.M.F. expended upon the terminals of the device. The writer has endeavored to obtain the desired result more through the medium of the filling than by the use of exceedingly long conductors. The size feature of enclosed

fuses has been one of the objections cited against them, where space is limited.

The mass of metal vaporized has an important bearing upon the satisfactory rupture operation of the fuse strip. With any definite tube section and length the arcing and explosive tendencies will primarily depend upon the temperature and volume of the confined heated vapor and air. In addition to the other considerations affecting the section and length of the conductor, maximum radiating surface is therefore desirable, owing to its effect upon the carrying capacity and essential size. It is also important that the conductor be in contact with the maximum amount of filling material in order to readily dissipate the heat of the expanding gases upon rupture. Several arrangements are possible: the subdivision of the fuse conductor into a number of separate strips connected in multiple between the terminals, but separated from one another so that each is entirely surrounded by the filling material, has been used (see *Fig. 13*). A simpler and more positive arrangement is used in the writer's fuses (*Figs. 14, 15, 16, 17*), consisting of a thin flat strip having the maximum contact with the surrounding mass consistent with mechanical strength. In connection with the desirability of reducing the metallic mass, it is regrettable that the necessity of limiting the melting temperature of the metal does not permit of obtaining the advantages in this direction resulting from the use of metals having a comparatively high melting point, and consequently larger carrying capacity for a certain section.

There are many insulating substances which from a casual inspection of the problem could apparently be utilized as a filling powder for surrounding the fuse wire. Investigation shows many of them to be lacking in the essential properties. The filling material should have even and unvarying thermal characteristics, and when placed in the fuse tube it should leave innumerable interstices between its particles. Coarse powders are best, as they provide the maximum contact with the gases, which thus part with their heat by conduction, combination or otherwise, and if not entirely dissipated in the filling, the remaining volume

readily passes to the exterior. It is a fallacy to assume that any combination of conductor and filling will be satisfactory. Ordinary lead-tin fuse wire could be surrounded by powdered chalk, retained by a suitable tube. Upon rupture, the disrupting tendency due to the expansion of the highly heated gases is checked and the arc broken up by the action mentioned. This combination is, however, defective, except on short circuit, where the disruption of the strip is absolutely assured, due to the tremendous heat energy suddenly impressed upon it. Under overload, it is deficient, because the oxide film supported by the filling material will hold the wire in a molten condition. The con-



FIGS. 19 and 19 A.—Sand-filled, 220 and 500 volts.

FIG. 20.—Chalk-filled, lead-tin wire.

PLATE F.—Sand and chalk-filled overload blown fuses.

tinuity of the highly heated conductor is maintained until mechanically disturbed, or the metal has been volatilized to the ultimate destruction of the tube.

RECORD OF TEST OF X SOLID-PACKED FUSE—GENERAL DESCRIPTION OF FUSE.

Grey fiber tube diameter ½ inch, length 2½ inches includiug brass ferrule caps at ends which served as contacts and to which tin-lead alloy fuse wire was directly soldered, extending from ferrule to ferrule centrally through a filling of white powder of chalky appearance and character. Fuse marked 6 and intended for 220 volt service. Not knowing what this rating was intended to imply, the fuse was started at 4 amperes and current increased.

4	Amperes	for	5	minutes	. . . . .	Block in which fuse was support well shaken after each interval. Tube hot.
5	"	"	5	"	. . . . .	
6	"	"	20	"	. . . . .	
7	"	"	15	"	. . . . .	At end of this time block given two quick raps and fuse opened. Tube abnormally hot.

With ordinary sand as a filling material the arc will probably be broken under short-circuit conditions. Such substances, however, conduct when melted. On overload, the molten filling in the small break space between the ends of the fuse wire will permit a current flux with sufficient resulting heat to finally detroy the complete structure. Fuse tubes filled with chalk and sand, blown on overload, are shown in *Figs. 19–20.*

In the enclosed fuse devices developed by the writer, a combination of the fused metal and the filling material is effected, but without any destructive action. Such combining action has advantages which will be noted later. Extensive experiment has been necessary to evolve a filling powder which would not maintain the continuity of the molten conductor or form destructive conducting combinations. To effect the first result an oxide dissolving or fluxing material is incorporated with the filling, and at melting temperature acts upon the oxide film surrounding the conductor in the same way that a quantity of borax thrown upon molten lead will clean off the oxide upon its surface. Recent developments indicate that non-hanging breaks can also be obtained by adjustments in the character of the metal employed, its section, radiating surface and the various heat properties of the surrounding filling, which can be made in the case of certain fuses. With the oxide fluxing filling, the rupture of the conductor is an absolute certainty irrespective of these considerations. (*Figs. 21, 22, 23* show ruptures of fuse strips surrounded with fluxing filling material).

A filling powder, to be properly operative, should possess certain thermal characteristics before and after rupture, and also possess excellent arc-killing properties. Greatly differing breaks can be obtained with a certain fuse strip, under

fixed conditions of rupture. The table (*Fig. 24*) shows the varying breaks obtained in a few of the materials tested.

Too much stress should not be laid upon a small break, as may be gathered from prior statements. A leak through the heated filling between the break-points after rupture may not be sufficient to cause a further melting of the conductor, and yet result disastrously, due to the extremely rapid temperature increase. Conductors, used in materials that show the slightest conducting tendency under heat

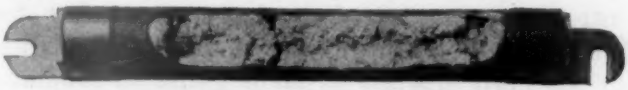


FIG. 21.—Short-circuit rupture of 500 volts, 50 amperes. Fuse showing combination.

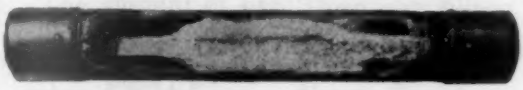


FIG. 22.—Solid packed 500 volts, 50 amperes. Ruptured by overload at normal voltage.

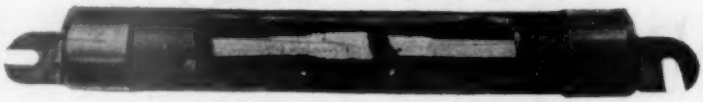


FIG. 23.—Solid packed fuse ruptured by overload at low arcless voltage. Note central location of rupture.

PLATE G.—Fluxing filling action on rupture.

action, must rupture with long breaks on overload. An enclosed fuse should therefore be tested under all conditions of service, both overload and short circuit; for while the enclosed fuse structure may operate satisfactorily upon short circuit, with its instantaneous, long rupture, the same strip in the same filling may operate very disastrously under the much smaller disruptive strain of a small overload. The break should be absolute to insure safe operation.

As much as possible of the liberated heat energy should be absorbed by the filling. The heat capacity of the filling is an important consideration in this connection. The use of a combining filling essentially absorbs some of the liber-

PLATE H.—ARC-RESISTING PROPERTIES OF FILLINGS.

Material.	Test.	Time.	Separation.	Material.	Test.	Time.	Separation.
		seconds.	inches			seconds.	inches
No. 2 Filling	1	15	3/16	Pulverized Alum	1	20	2 5/16
"	2	10	7/16	"	2	16	3/4
"	3	11	1 3/16	"	3	18	3/4
Slaked Lime	1	18	3/16	Fine S. S.	1	17	11/16
"	2	6	1 1/2	"	2	16	5/16
"	3	8	7/16	"	3	16	5/16
Gypsum	1	20	1 3/16	A. Silex	1	14	11/16
"	2	8	7/16	"	2	13	1 3/16
"	3	10	1 5/16	"	3	14	1 3/16
Chalk	1	12	1 5/16	No. 13 Filling	1	22	1 5/16
"	2	8	1 5/16	"	2	10	1 3/4
"	3	9	1 3/4	Portland	1	10	1 7/16
Competing	1	7	11/16	Cement	2	12	1 1/2
Filling	2	7	1 1/16	No. 3 Filling	1	8	5/16
"	3	9	1	"	2	10	1
Heavy Magnesia	1	9	1 1/2	"	3	11	1 7/16
"	2	10	1 3/4	No. 14 Filling	1	6	1
"	3	10	1 5/16	"	2	10	1
No. 15 Filling	1	10	1 1/16	"	3	9	3/16
"	2	10	1	No. 5 Filling	3	10	11/16
Mica	1	6	1 3/4	No. 6 Filling	1	8	3/4
"	2	7	1 5/16	"	2	10	7/16
No. 5 Filling	1	12	7/16	"	3	10	7/16
"	2	12	11/16				

Fuse strip ZN .018 x .170 x 3 inches.
Fiber tube, ¾ inch diameter, 5½ inches long.
Overload current 50 amperes, 220 volts inductive load.
Clamp block opened and break measured after each rupture. J. P. Co. Lab., 10-8-20.

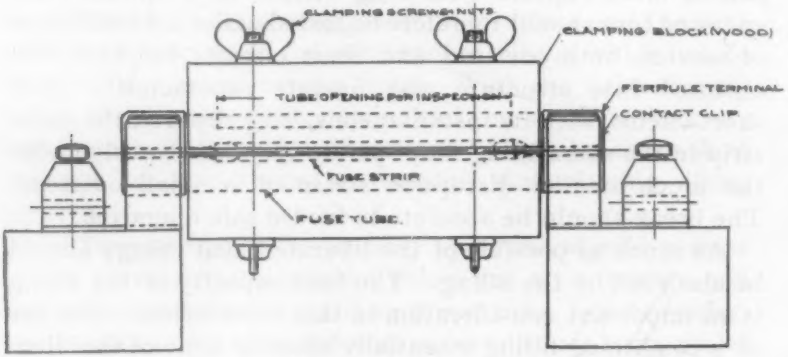


PLATE H.—FIG. 24.—Table of arcing distances and testing apparatus.

ated heat energy. The writer has demonstrated that fuses based upon a proper adiustment of these properties show a reduced external gas demonstration upon rupture. The break with a combining effect is also less abrupt than where the heat energy is dissipated by conduction alone.

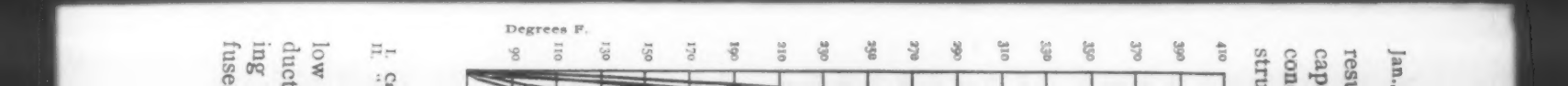
For obvious reasons, the temperature attained by the complete structure must be minimized, and the effect of the thermal properties of the filling material on the time interval of operation under overload conditions should be investigated. The heat capacity and total mass affects the time-interval of operation prior to rupture. Reduction in the total amount of filling material detracts from the rupture operation. With ample surrounding filling, the heated vapors resulting from any excess-current condition can be dissipated. The amount of heat-absorbing filling material and the consequent size of the retaining tube are governed by both the carrying capacity and voltage of the enclosed fuse strip. While the section and length of tube and enclosed mass of filling material around the fuse strip directly control its active operation on rupture, commercial considerations somewhat limit the size of the complete device. The table following gives some general tube and fuse-strip dimensions.

Some consideration must also be given to the disposition of the fuse strips relative to the tubular casing. Since the rupture should be entirely surrounded by the filling material, the fuse strip is preferably connected between terminal wires of better conductivity extending from the tube-closing ferrules into the filling. Vented ferrules are necessary on large fuses.

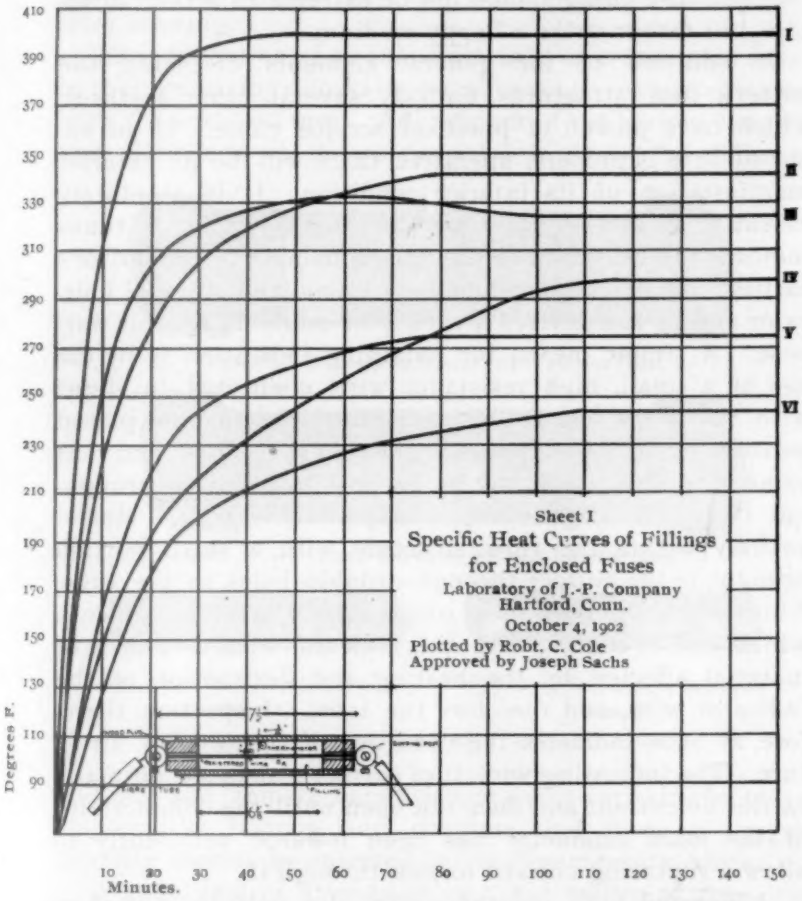
Fig. 25 shows some curves of heat capacity and behavior of substances available for fuse fillings. The filling material under test was held around a small electrically heated conductor by a fiber tube, and the temperature of the filling just inside of the tube taken at intervals until an even temperature had been reached. Materials showing a large specific heat capacity and a low maximum temperature will increase the carrying capacity of a certain fuse conductor, but decrease its sensitiveness to current changes with

PLATE Q.—LENGTH AND DIAMETER OF TUBES AND LENGTH OF STRIPS. "SACHS'" FUSES.
(Given tube length is over ferrules).

Volts.	Class Amps.	Tube Length.	Tube Dia.	Fuse Length.	Volts.	Class Amps.	Tube Length.	Tube Dia.	Fuse Length.	Volts.	Class Amps.	Tube Length.	Tube Dia.	Fuse Length.
		inches.	inches.	inches.			inches.	inches.	inches.			inches.	inches.	inches.
220	1-8	2 3/8	3/8	1¼	500	1-10	4⅝	⅜	3	2,500	1-12	5¾	½	4½
	10-15	2 3/8	⅜	1¼		12-25	5¼	½	3		15-30	5¾	⅝	4½
	20-30	3 1/8	½	1½		30-50	5¾	¾	3		35-50	6¼	⅞	5
	35-50	3¾	¾	1¾		60-100	6¼	1	3½		60-75	6 1/8	1⅛	5½
	60-100	4⅛	⅞	2		125-150	6¾	1¼	4		80-100	6 1/8	1¼	5½
	125-150	4⅛	1	2½		175-225	6 7/8	1½	4					
	175-225	4 1/8	1¼	2½		250-400	6⅞	2	4					
	250-400	4 1/8	1½	2½		500-600	10	2½	4					
	500-600	6 1/8	2	2½										
5,000	½-12	15⅛	¾	13	10,000	½-12	24	¾	18	20,000	¼-10	30	1	24
	15-30	15⅛	1	13		15-30	24	1	18					
	35-50	18⅛	1⅛	14										



resulting slow overload operation. Increased carrying capacity, however, results in a larger heat output from the conductor with increased temperature in the entire fuse structure, at the maximum continuous load. Materials of



I. Carbonate of Magnesium.
II. "H" Silex.
III. "100" Mica.
IV. Crayon Chalk.
V. Asbestic.
VI. Fine Soapstone.

PLATE I, FIG. 25.—Heat capacity curves.

low specific heat minimize the carrying capacity of the conductor, due to the fact that the heat units absorbed in raising the temperature are comparatively small. Enclosed fuses, in which fillings of this nature are used, operate at

a lower temperature and show a smaller time-interval in adjusting themselves to load changes. The heat capacity of the filling also affects the rupture operation. Maximum heat should be absorbed in raising the temperature. An enclosed fuse filling should not be extreme in either direction, but rather strike a happy medium.

In addition to the general elements discussed, the writer's fuse structures embody several other features, which have proven of practical service value. If an enclosed fuse is properly operative, there will be no exterior manifestation of its interior condition. It is absolutely essential, therefore, that means be provided to at all times indicate the condition of the fuse conductor. The writer's earliest commercial developments embody an external indicator and he has devised a variety of methods for this purpose. A simple means for obtaining indication is by the use of a small, high resistance wire, connected in shunt with the main fuse. This indicating wire may be placed entirely upon the exterior surface of the tube and left exposed to view, or it may be covered by a paster throughout its entire length; but it is preferably placed almost entirely within the tube structure with a small portion brought to the surface through suitable holes in the tube. This indicating portion is covered by a label, underneath which, and in contact with the indicator wire, is a spot of material affected by the heating and destruction of the indicator wire, and discolors the label. Inspection, therefore, at once indicates the condition of the interior structure. The indicating wire, if of correct resistance, normally carries no current and does not open until the conductivity of the main conductor has been lowered sufficiently to allow a rupturing current to pass through it.

A shunted high resistance wire also indicates the character of the interior disruption. The disrupting manifestation of an indicator wire entirely exposed on the surface of a tube containing an interior main-fuse fire is very slight. The same wire, without any interior main-fuse conductor, opens with comparatively severe disruptive effect. This action is due to the gradual break in the main-fuse wire.

In passing from its maximum to zero conductivity it is at some particular instant equal in resistance to the indicator. Disruption of the indicator follows, but the final break takes place in the interior conductor. *Figs. 26, 27, 28, 29* show this action and also the "spot" indicator before and after blowing.

The prevention of an indiscriminate interchange of fuses in their receiving blocks is an advantage readily obtained with the enclosed fuse. Adjustment of the various lengths and diameters, which are essential in fuses for different

FIG. 26.—Exposed indicator with interior fuse.

FIG. 27.—Exposed indicator without interior fuse.

FIG. 28.—Sachs' spot indicator unblown.

FIG. 29.—Sachs' spot indicator blown.

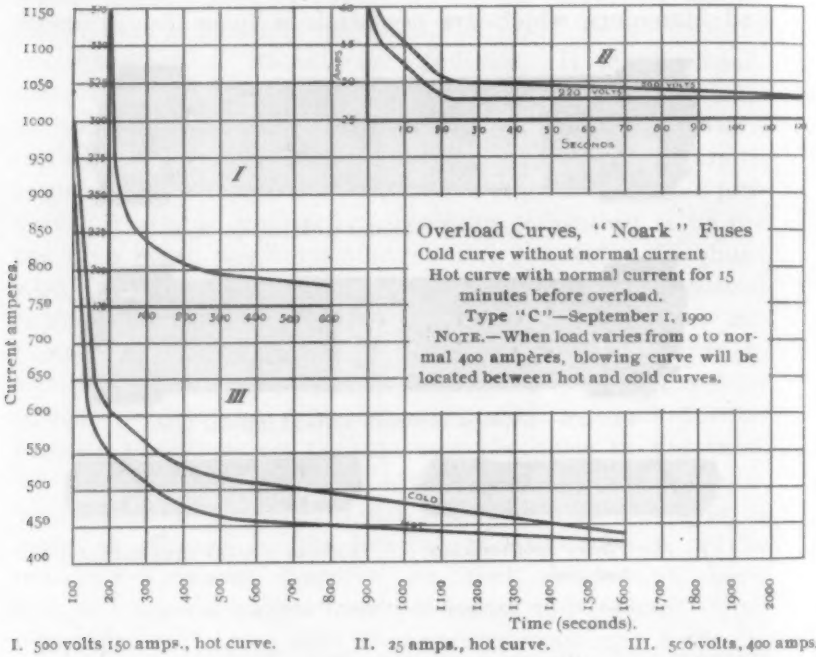
PLATE J.—Exposed and "spot" indicator action.

voltages and ampere capacities, make it very simple to so dispose the fittings and contacts that fuses of larger capacity cannot be inserted in smaller capacity blocks.

A great deal of discussion as to the rating of fuse-protective devices has been indulged in within recent years, and it is regrettable to note that the National Electric Code embodies amongst its enclosed fuse requirements a rating clause as follows:

"Must be rated at 80 per cent. of the maximum current which they will carry indefinitely," etc.

The writer has always maintained the incorrectness of this system of rating. In his opinion, a protective device should be rated on the same basis as the apparatus which it protects; that is, at its maximum capacity for continuous service. In order, however, to comply with the above-mentioned requirements, both the maximum carrying capacity and the code rating (80 per cent.) are placed upon the fuse.



I. 500 volts 150 amps., hot curve. II. 25 amps., hot curve. III. 500 volts, 400 amps.

PLATE K, FIG. 30.—Overload time curves.

All of the writer's fuses embody very much the same structural elements in the way of fiber tubes, filling, fuse wire, terminal wire, and a variety of contact arrangements. In the development of the latter it has been the aim to provide screw-driverless contact fittings, so that the manipulation of the fuse device does not require the use of tools, even for the larger current capacity. The service requirements at the several commercial voltages have been care-

fully studied. Some of the different forms of blocks, fittings, contacts, etc., are illustrated.

THE OPERATION AND APPLICATION OF ENCLOSED FUSE DEVICES.

The enclosed safety fuse is essentially a time-interval protective device. The fuse environment serves as a heat reservoir, whose properties give to the device the much desired time-interval function. At the same time, however, it will resist or insulate a heat input beyond its capacity, which feature, taken in conjunction with the increase in resistance as the temperature of the wire rises, produces very rapid decrease in the time-interval under extreme conditions. The overload curves, *Figs. 30–31*, show these characteristics. In standard fuses, overload time-intervals as follows have been adopted. These may appear somewhat small for certain purposes, but it was found necessary to meet the average requirements.

220 volt	fuses	to and including	15 amp.	blow at	25	p.c.	overload	in	15–30	sec.
"	"	"	from 20–150 amperes	"	"	"	"	"	"	30–60	"
"	"	"	" 175 " up	"	"	"	"	"	"	100–300	"
500	"	"	to and including 25 amp.	"	"	"	"	"	"	15–30	"
"	"	"	from 30–150 amperes	"	"	"	"	"	"	60–100	"
"	"	"	" 175 amperes up	"	"	"	"	"	"	100–300	"
2500	"	"	to and including 12 amp.	"	"	"	"	"	"	15–30	"
"	"	"	from 15–100 amperes	"	"	"	"	"	"	30–60	"

These time-intervals are for fuses that have been in circuit for some time and with a temperature of 75° F. in the surrounding atmosphere.

Every effort is made to reduce the factor of error in manufacture. About 5 per cent. allowance each way in the maximum carrying capacity of such devices is not beyond reasonable limits, and a slight variation of the overload time-intervals is also to be expected.

The continued integrity of a fuse wire surrounded by substances of the character used in filling materials, and particularly those containing fluxing mediums, has been questioned. A multitude of the writer's fuses in service have not yet demonstrated that there is any such action. It is, however, obvious that if at any time the wire reaches its melting temperature the condition of the fuse-strip is

affected, even though the abnormal condition ceases before rupture occurs. The fluxing medium, or other component parts of such fillings, show no deteriorating action until the melting temperature has been reached and continued for a sufficient time.

It is obvious that a structure embodying the heat properties inherent in an enclosed fuse will have a somewhat different time-interval of operation when first put into service than it possesses after operating for some time at normal current conditions. The ratio of these relative time-intervals is less than would be expected, although it increases with the size and capacity of the fuse, as is shown by the following test-record.

HOT AND COLD OVERLOAD TIME—SOLID PACKED FUSES.

Rating.	Carried.	Time.	Overload.	Opened.	Ratio Hot to Cold.
500 volts, 40 amperes, flat single fuse.	40 a	1 hr.	50 a 50 a	55 sec. 210 sec.	11 to 42
500 volts, 25 amperes, flat single fuse.	25 a	1 hr.	30 a 30 a	45 sec. 195 sec.	3 to 13
2,500 volts, 50 amperes, flat single fuse.	50 a	1 hr.	62½ a 62½ a	30 sec. 120 sec.	1 to 4
220 volts, 10 amperes, round single fuse.	10 a	1 hr.	12 a 12 a	10 sec. 30 sec.	1 to 3

To demonstrate the rapidity of action of the enclosed fuse strip, a very simple test is made by connecting an enclosed and exposed fuse strip in series, both strips being of the same metal and identical in section and length. The record of such a test given here shows by the less vehement disruption of the exposed strip, when disrupted in series with the enclosed strip, that the latter operated first, breaking the arc.

COMPARATIVE 500-VOLT SHORT-CIRCUIT TEST OF FLAT STRIPS IN SOLID-PACKED CASE AND AIR EXPOSED.

Open and enclosed fuses, rated 40 A. 500 V. enclosed. Flat strip ·018 × ·13 × 3 inches between copper terminal wires ·11 diameter, 6¼ inches between center of contact posts.

Exposed Fuse Strip Alone.—Very severe arcing and burning of terminal wire back to posts. Break 6 inches.

Exposed Fuse Strip in Series with Enclosed Strip.—Both fuses opened but exposed strip simply disrupted in terminal wires without any burning and only slight snap. Break 3 inches in each exposed fuse.

Varying conditions of abnormal current result in correspondingly severe shocks to the enclosed fuse structure. The disruptive strain upon the protective device varies with its location, the capacity of the generating apparatus, the

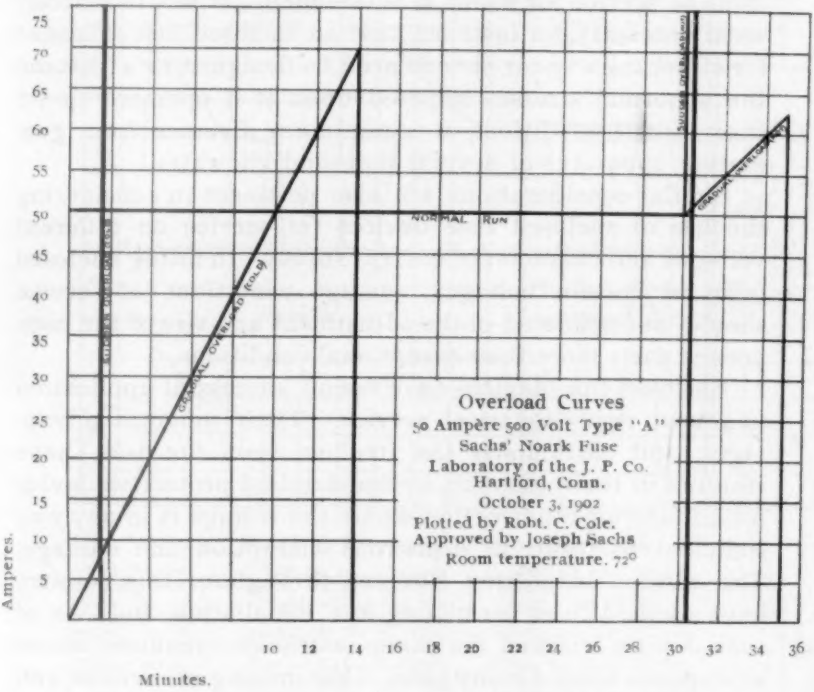


PLATE L, FIG. 31.—Overload time curves (gradual and sudden overload).

amount of load other than that imposed upon the fuse device, the power factor of the system protected and the ability of the current source to maintain the working voltage. Where abnormal current suddenly demanded from the current-supplying apparatus causes a momentary reduction in the working potential, the stress imposed upon the protective device at the moment of rupture is very much less than if the E.M.F. and current are maintained. With

over-compounded generating apparatus, small armature reaction or low-power factor, short circuits are of maximum severity. While enclosed fuse devices can be constructed to meet the most severe condition under any service, practical commercial limitations prohibit free sway. The writer has always maintained that a protective device need only accomplish satisfactory results under the particular conditions of service for which it is intended. It would scarcely seem necessary, for instance, that an enclosed fuse intended for street railway-car service need be designed to withstand the abnormal stresses imposed upon it if operated under short-circuit conditions at a minimum distance from generating apparatus of several thousand kilowatts.

Similar considerations are also pertinent in considering the use of enclosed fuse devices for service on different voltages and character of current supply. In rating enclosed fuses at certain voltages, average conditions of service should be considered in the adjustment and size of the component parts more than exceptional conditions.

Enclosed fuse devices have found successful application in almost every electrical service. Their inherent advantages, and particularly the freedom from fire-risks, have resulted in their adoption as the standard protective device for all interior construction where the voltage is in any way sufficient to result in disastrous disruption and damage. The various Inspection Bureaus throughout this country have adopted rules permitting the installation and use of such devices without the many restrictions required where air-exposed fuses are installed. Minimizing of careless and indifferent fusing, in cases where this is done by inexperienced persons and easy manipulation, is another advantage universally recognized.

As a motor-protective device the enclosed fuse may well be said to be ideal, since it possesses all of the operative elements essential for correct motor protection. The time-interval function in such applications is undoubtedly essential. On the electric railway service, enclosed fuse devices have been used very extensively for the protection of the car motors. As an instance, it may be stated that there are

over six thousand surface trolley cars protected with enclosed fuse equipments, and they have also been adopted for the protection of the motor equipment of nearly all of the large elevated railways. Railway managers seem to have found that time-interval operation, accuracy and safety obtained by the use of such devices have minimized repairs accounts

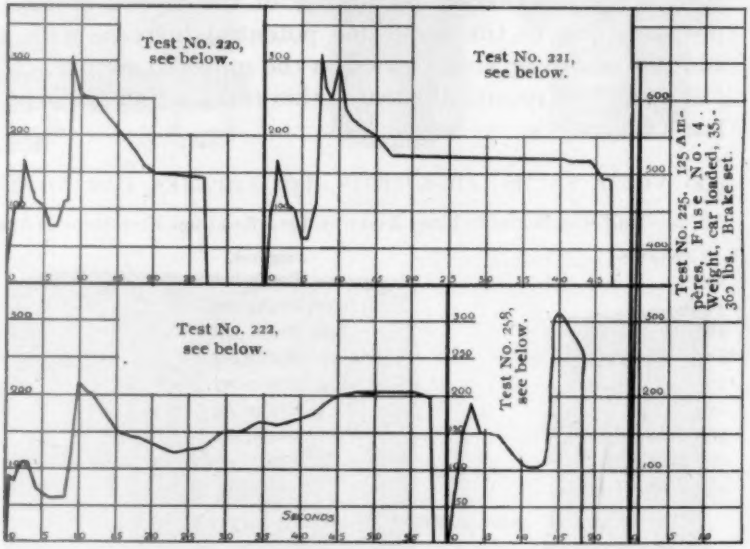

Test No. 220, see below.
Test No. 221, see below.
Test No. 222, see below.
Test No. 223, see below.
Test No. 225. 125 Amperes, Fuse No. 4. Weight, car loaded, 35,360 lbs. Brake set.
Test No. 238. Fuse, 100 Amperes. Fuse opened at 315A. Fuse No. 1.
SECONDS

PLATE M, FIG. 32.—Car operation curves.

Test No. 220, 125 Ampère, Fuse No. 2. Weight, car loaded, 25 360 lbs. Ascending grade, 2 per ct. Distance run by car, 404 feet. Fuse held. Curve shows current input during this time.

Test No. 221. 125 Ampères, Fuse No. 2. Weight, car loaded, 35,360 lbs. Ascending grade, 4·63 per ct. Distance run by car, 816 ft. Fuse held. Curve shows current input during this time.

Test No. 222. 125 Ampères, Fuse No. 2. Weight, car loaded, 35,360 lbs. Ascending grade, 5·17 per ct. Distance run by car, 799 ft. Time to fuse blowing, 58½ sec. Curve snows current input during this time.

and damage suits. Actual tests of car-service operation of enclosed fuses demonstrates their peculiar fitness for the purpose. The curves, *Fig. 32*, show actual tests made by the engineers of a large street railway system and indicate the peculiar operative features under such service. Comparative tests made with electro-magnetic circuit breakers and enclosed fuses show a marked difference when the

motion of the car is brought to a stop by the opening of the protective device. In the case of the circuit-breaker operation the cessation of motion is of a jerky nature, whereas, with the enclosed fuse, the slowing down is very gradual and is not noticeable by any disagreeable effect of the character mentioned. The undesirable result in the case of the instantaneous rupture of the circuit breaker is probably due to the inductive potential increase with the sudden resulting acceleration in the motor armature. The following test-record illustrates this feature and other peculiar advantages.

500 VOLTS SACHS' FUSE TESTS, 150 AMPERES, CAR NO. 635.

No. 2.—Half-way House to Pines River Bridge. Readings Five Seconds Apart.

Amperes.	Amperes.
245	205 Brake set.
305X	205 Brake set.
225	245 Brake set.
155	245 Brake set.
135	245 Brake set.
125	235 Brake set.
165 Brake set.	235 Brake set.
205 Brake set.	215 Fuse blown, car stopped without a jerk.
230 Brake set.	

RUN CONTINUED WITH NEW FUSE.

Car off track at Revere Street.

Circuit breaker out five times. (Had to be held in to get car in position again.)

Fuse did not blow.

No. 6, 150-ampere fuse blown, throwing overhead switch on short circuit.

No. 7, 60-ampere fuse blown, throwing overhead switch on short circuit.

The unalterable fixing of the motor behavior due to the limitations imposed upon it by the protective device make it possible to check the behavior of motor equipments in actual service and thus by timely repairs minimize the maintenance account. The relative merits of enclosed fuses and other devices for motor-car equipment protection scarcely require discussion. The fact remains that comparative tests under actual service conditions certainly indicate the advantages of the enclosed fuse. The advantages resulting from the use of the enclosed fuse in railway

PLATE N.—220-volt Sachs' enclosed fuse devices.

A, three-pole 20–30 amperes main line block type "B." *B*, single-pole 60–100 amperes main line block type "C." *C*, enclosed fuse plug for Edison cutouts (interchangeable fuses). *D*, switch and fuse combination for panel boards.

service are also apparent under most other conditions of motor service.

The value of non-arcing protective devices on potentials of 1,000 volts and above cannot be over-estimated. Innumerable arrangements have been utilized to minimize the arc resulting from rupture, many of which are very satisfactory, although complicated and expensive. The enclosed fuse has found a most prolific field in this direction. While it has already been developed for a multitude of services at these higher potentials up to, say 2,500 volts, great possibilities are to be expected from future developments and improvements. As a line cutout on alternating systems the enclosed fuse is being very extensively used, to the displacement of other devices. In the very high transmission system potentials, reaching up to 20,000 volts, some very satisfactory results have been forthcoming. The serious disadvantage, however, in the enclosed fuse for this purpose is the necessity for exceedingly great length, which objection, however, the writer hopes to overcome in the near future.

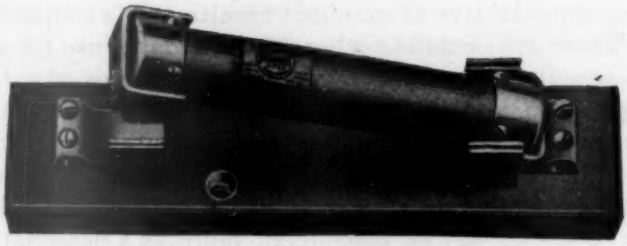
Safe and accurate fuses can now be obtained for standard electrical service, in capacities as follows:

220	volts	up	to	1,000	amperes,	D.C.
500	"	"	"	600	"	"
1,500	"	"	"	200	"	A.C.
2,500	"	"	"	100	"	"
5,000	"	"	"	50	"	"
10,000	"	"	"	30	"	"
20,000	"	"	"	10	"	"

Higher voltage fuses have also been constructed and tested, but no standard device has been developed as yet. Single fuses, which normally control nearly 400 kilowatts of electrical energy at 600 volts, and which rupture under short-circuit conditions on current values reaching thousands of amperes, are in daily successful operation. In several cases single fuses have been connected in multiple with an aggregate capacity of three or four times the above. On 2,500 volts A.C. successful opening of short circuits at the bus bars of about 1,000 kilowatts of generating apparatus with

E

F



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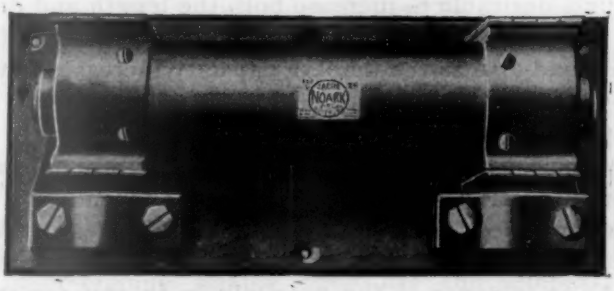


H

PLATE O.—500 and 2,500 volt single-pole Sachs' enclosed fuse devices. *E*, 2,500 volt, 50 amperes, type "A" cutout. *F*, 500 volt, 25 amperes, type "B" cutout. *G*, 2,500 volt, 100 amperes, type "D" cutout. *H*, type "C" 500 volt, 600 amperes, heavy traction cutout.

a holding voltage has been successfully accomplished with scarcely any exterior gas manifestation, the normal fuse rating being 100 amperes.

Multiple or series arrangement of enclosed fuses is not recommended. Where two or more fuses are used serially, they must all open simultaneously. The entire rupture effect will otherwise be imposed upon the fuse which opens first, resulting in its probable destruction. Practical manufacturing conditions prevent absolute duplication of the various physical characteristics in a device of this type. Absolutely uniform conductivity in each of the parallel fuses is, therefore, as impossible as absolutely simultaneous action in the series-connected fuses. Unless ample allowance is made for the uneven division of the current, a multiple combination will blow when unnecessary. The use of enclosed fuses on voltages below that for which they are rated is productive of excellent results and is frequently done. There are occasions where the standard fuse for any particular voltage does not give a sufficient factor of safety in its operation, and increased size, intended for the same ampere capacity at a higher voltage, is desirable. It may be noted that ruptures under certain 2,500-volt A.C. conditions are less severe than bad conditions at 500 D.C. The voltage rating should be considered more as a designation indicating the energy-rupturing ability of the fuse. It has been found desirable to increase both the length and diameter of the tube for a certain ampere rating as the voltage increases, and also as the ampere capacity increases with a certain voltage.

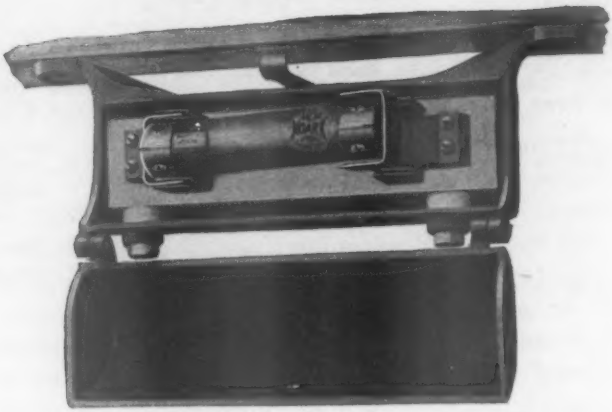
Comparatively higher first cost is probably the only reason why enclosed fuses have not already entirely displaced the open fuse wire or link. After the first expenditure, the use of an enclosed fuse structure is relatively cheap. Well-constructed enclosed fuses can be refilled and used repeatedly. As an instance of the possibilities in this direction, the following record of a refilling test is given:

TEST NO. I (REFILLING) 500 VOLTS, 150 AMPERES, STANDARD "D" SACHS' FUSE, ROOM TEMPERATURE 70° F.

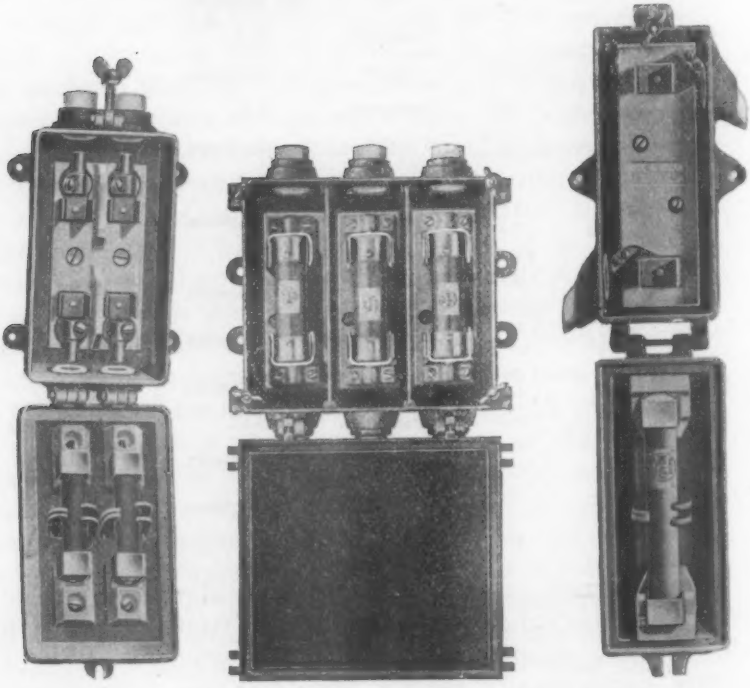
Same tube blown and refilled. Tube good for further use at end of Test 25.

Run No.	Date.	Voltage.	Time.	Current.	Remarks.
1	12/27/'01	500	Instantly.	S.C.	O.K., no gas.
2	"	500	"	"	" slight gas.
3	"	500	"	"	" "
4	"	500	"	"	" gas.
5	"	500	"	"	" no gas.
6	12/28/'01	500	"	"	" "
7	"	500	"	"	" "
8	"	500	"	"	" "
9	"	300 / 500	Unknown.	375 Amperes.	" "
10	"	500	Instantly.	S.C.	" "
11	"	350 / 500	63″	250 Amperes.	" "
12	"	500	Instantly.	S.C.	" "
13	"	375 / 500	360″	200 Amperes.	" "
14	12/29/'01	520	Instantly.	S.C.	" gas.
15	"	300 / 325	6″	400 Amperes.	" no gas.
16	"	520	Instantly.	S.C.	" gas.
17	"	325 / 500	16″	320 Amperes.	" no gas.
18	"	500	Instantly.	S.C.	" "
19	"	300 / 500	9″	405 Amperes.	" "
20	"	250 / 400	21″	310 Amperes.	" "
21	"	300 / 500	13″	335 Amperes.	" "
22	"	500	Instantly.	S.C.	" slight gas.
23	"	300 / 475	22″	310 Amperes.	" no gas.
24	"	300 / 475	33″	290 Amperes.	" "
25	"	510	Instantly.	S.C.	" "

Large current capacity enclosed fuses develop material heat when operating at the maximum continuous load, and the resulting temperature has been objected to. With a certain commercially salable tube size the temperature effect becomes a forced evil if the fuse has a satisfactory rupture operation. Lower temperature, under such condition, usually implies more metal in the the conductor. Excessive tube size, for obvious reasons, is impracticable.



I



J *K* *L*

PLATE P.—Sachs' enclosed fuse and service boxes.

I, 500-volt car equipment. *J*, 220-volt service box acting as fuse and switch. *K*, three-pole, 220 volt, 225 amperes fuse box. *L*, single-pole, 2,500-volt transformer service cutout box.

Such temperature effects must, therefore, be looked at in the light of a necessary evil for the present. Improvement in this feature, consistent with satisfactory size and rupture, is a development of the near future. That heat and resulting increase in temperature are necessary accompaniments of thermal-protective devices should always be remembered by the user.

In conclusion, the writer believes that enclosed fuse-protective devices, if properly designed, can be constructed to operate accurately and safely at almost any abnormal condition. While many features require further development, and excessive size and cost may present obstacles in instances of particularly severe rupture effect, ultimate results will, no doubt, prove enclosed fuses the standard for all service.

NEW METHOD OF ARMOR-PLATE MAKING.

A new process of supercarbonization, or "face-hardening" of armor-plate, has been developed by an officer in the American Navy which promises to exert a greater influence upon the struggle for supremacy between guns and armor than was produced either by the American Harvey or the German Krupp processes before it. The method of increasing the resistance of homogeneous armor-plate by hardening its face may be said to have originated in this country when Harvey introduced his process of increasing the hardness by causing the surface of the plate to take up an excess of carbon during treatment in the furnace. Armor with a hard face upon a tough back had, it is true, been already produced abroad, the compound armor, which so many of the old English battleships carry, being of this character. But compound armor had the serious defect that the hard face consisted of a separate plate of steel welded upon a backing of softer and tougher metal. The hard face was secured at the expense of homogeneity, and the serious nature of this defect was realized at the proving grounds when the surface flaked and broke away from the softer back, leaving the plate open to penetration by shells of small caliber. The incontestable superiority of the Harvey armor led to its all but universal adoption throughout the world. Krupp eventually improved upon it, substituting gas treatment in place of the layer of carbonaceous material used in the Harvey method, and also improving the quality of the plate by very careful attention to the details of the furnace treatment. While the high quality of Krupp plate is unquestionable, its excellence is gained at enormous cost as high as $550 per ton having been paid for this class of armor.

The invention of Lieut. Cleland Davis, of the Navy, marks, both in effectiveness and in cost of manufacture, a great advance upon the Krupp system. His method includes the substitution of electrical currents for the heat of the gas-fired furnace, and the direction of these currents against the face of the

armor-plate while it is in a heated condition by means of massive carbon anodes, in form not unlike the carbons used in arc lights, but of vastly greater size. During his course of experiments, Lieutenant Davis found that if a current of electricity were sent from a carbon into the surface of a plate, it carried with it a certain amount of the carbon and implanted it within the body of the metal. The depth of the hardening is determined by the period of time during which the current is applied, and it is claimed that not only is the surface thus treated harder than that treated by the Krupp process, but the depth to which the hardening is carried is increased. The economy of the process may be judged from the statement that while the Krupp plate is kept in the soaking pits at a heat for from fifteen to twenty days, the same amount of impregnation with carbon is obtained with the Davis process in five hours.

The experimental plate was made at the works of the Bethlehem Steel Company. A moderate thickness, 5 inches, was chosen, and the only complaint made against the quality of plate was that the hardening of the face was not uniform, a fault which is attributed by the inventors and makers entirely to the experimental nature of the electrical appliances employed and not to any inherent defect in the process. In the next plate that is fabricated, carbon rollers are to be substituted for the present anodes, and with these it is expected that a uniform depth and hardness of carbonizing will be secured. It is estimated by Lieutenant Davis that, as compared with Krupp plate of equal resistance, the new system will produce plates from 20 to 30 per cent. lighter in weight. Further developments of this process will be watched with the greatest interest, and should it prove possible to secure these remarkable results on a commercial scale, the effect upon warship construction will be more radical than anything that has happened in the naval and coast defence world for many years.

It is possible that in the new plate the Navy has made answer to the new high-explosive shell.—*Scientific American.*

OIL AS FUEL FOR LOCOMOTIVES.

Most of the roads reaching the recently developed oil-fields in the Southwest are actively engaged in making the necessary changes, or have preliminary arrangements under way, whereby oil will be used as locomotive fuel on the equipment operating locally in this territory. There is economy in the use of oil in comparison with coal in this district, where the cost of coal is above and the quality below the average, but just how much is as yet undetermined from reliable information. Conservative estimates, says the *Railway Age*, place the saving at from 15 to 20 per cent. This reduction is not based on the relative cost of actually producing one horse-power by use of coal or oil as fuel, but involves the comparative cost of the handling of both, and it is from this source that the greater proportion of the economy must be looked for, as in some instances the actual cost of the amount of oil used for fuel has exceeded the cost of coal in performing similar service. This may possibly have been due to improper combustion, but it illustrates the fact that care must be taken in the selection of the proper appliances for using oil to effect an economical consumption. W.

PHYSICAL SECTION.

Stated Meeting, held Wednesday, May 28, 1902.

The Culture Value of Physics.

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Culture is a polyedron of very many faces. It is a crystal that changes its aspect as it changes its position relative to the observer. In order, therefore, to describe it, we must give separate consideration to each of its different parts. This statement, however, does not exempt one, who wishes to treat of it, from endeavoring to give some distinctness to its general configuration.

The word "culture" is so vaguely used, not only by the masses but by educators as well, that it seems like a faint and distant light in a dark and dreary cave, shining uncertain and shading into a misty night. The word is most commonly used in a vague contradistinction to knowledge. The acceptance of this meaning exerts a very pernicious influence, for it frequently gives rise to the belief that the more useless the work the more thankless the task, and the less the knowledge derived the greater is the mental training received. The most striking corollary of this is the absurd "Discipline of Difficulties" which would have us, somewhat in the manner of the ant, back with our burden over every obstacle that can be found in a circuitous path. For the present purpose I shall consider the culture, discipline, training, received in an intellectual pursuit, as the indirect or mediate as distinguished from the direct or immediate use of knowledge; or to express it differently and perhaps to shade the meaning a trifle—as the permanent effect on a being of knowledge and of the method of getting knowledge. Having thus endeavored to mark the outline, I shall proceed to examine some of the faces of the polyedron.

Before entering upon a somewhat perilous sea, let me assure you that I am not taking as ballast a departmental psychology. As I am not taking such a ballast, please

excuse us from the disagreeable, cheap and useless task of going through the motions of throwing it overboard.

At the first glance, physics seems to have nothing whatever to do with the training of the will. Indeed, it would be foolish of us to expect it to replace the formal study of ethics, and it would be wrong for us to intrust it with the inculcation of the highest and most refined sense of duty. But a closer inspection reveals the fact that our subject makes a very definite call on the activities. The movements necessitated in the laboratory are of use in regulating random motion, in adjusting means to ends, in cutting off a number of useless adjustments in order that the remaining ones may have greater speed and certainty, and in handing to automatism and semi-automatism simple movements that the attention may be given to the more complex ones. Besides, the knowledge obtained in all departments of the subject induces a response to the higher stimuli, such as the deference to remote ends, the abstract sentiment of futurity, the love of truth and the desire to progress. Where the student is more or less initiated into the spirit, thoughts and inspirations of the semi-recluse (as he is in a pursuit of physics), it speaks well for the effect of his subject on the will when there are few of its votaries suffering from the malignant form of the disease prevalent among the inactive. I speak of asceticism which finds so few victims in an age in which physics counts so many adherents. But we must not congratulate ourselves too complacently, for many of the immunes are inoculated by simple worldliness which causes the motives as well as the work to become not pure, but applied, and substitutes contrivance for investigation. Moreover, there is still a mild form of the disease prevailing, which is shown by the fact that those whose systems are yet unsullied and who seek pure truth are apt to find action in the world at large more or less distasteful.

But surely, it is safe to say that a man's conscience is modified by a pursuit of physics in its several departments. We should all be surprised should a natural philosopher behave like a child or like one untaught. Even a very imperfect habit of investigation and reflection must cause

many acts, which before gave pleasure, to become more or less painful.

In the culture of the feelings as in that of the will, physics plays a somewhat subordinate part. We should not think of its awakening the stronger feelings of love and hate, nor should we expect it to replace the formal study of æsthetics. It, however, addresses the altruistic emotions and aids in producing a truth-seeking disposition. This it does by the investigation of facts and their relations; but this investigation of fact does not preclude the introduction of form. Frequently do we hear it said that one may be legally right and yet morally wrong. Can it also be said that a statement may satisfy the requirements of natural philosophy and still leave an adverse moral conviction? Is it at all possible that what Sidgwick calls the *cosmic emotion* is partly composed of sentiments *ultra* and sentiments *infra* physical? "Ultra" I use to refer to the higher complex speculations, and "infra" to refer to those emotions of everyday life which are so unscientific and yet so persistent. Lotze says: "I do not think that physics does aught to resist intuitable fact; it merely insists that all investigation be carried on by its own laws." Let us claim indulgence long enough to inquire whether it be for the best permanent interest of truth for physical science to impose its laws on all other branches of inquiry. Can there possibly be other fields of knowledge requiring other postulates and other modes of research? This is mere fanciful speculation; but, if it be at all legitimate, there is a field of inquiry to the emotions of which physics contributes no positive aid.

If physical laws apply to all things, our science needs improvement in cultivating those nicer sentiments in which its devotees are often so signally weak. There is "a time to keep silence and a time to speak," and moreover, there are occasions when it is well to soften the harsher truths of everyday existence. One's finer feelings should free him from the brutality of unseemly and unnecessary truth. A man is a boor who is constantly blurting uncalled-for facts. It is by a mind cultivated by many classes of truths that the human being receives due consideration as a factor in

the progress of humanity. Individual feeling must sometimes be set aside for truth's sake, just as individual life must be made subservient to the life of the community. However that may be, it is certainly true that the feeling as well as the life of the individual is deserving of recognition.

This consideration of the feeling for others' feelings brings us to polite culture. It is but little positive aid that our science renders here; but, in behalf of the science, be it said that arduous work in the field of fact and stern reality must ever tend to keep one from being cultured past his powers and so becoming effeminated. To be cultured without being wise is of little use to progress; and is, in many respects, like being brave without being strong. Over-refinement may over-awe timid men and those unskilled folks who seek superiority in others and ever look for some one whom they can follow; but it must fall before the uncouth strength of stern unvarnished truth. In this way will be lost the good derived from those facts that are fearlessly true, yet softened, gentle, and mild. Let us step out of our own field long enough to pick a specimen for demonstration. The study of ancient wars as pursued in the classics tends rather to produce a Brummel than an Achilles; but the pursuit of tactics and the experience gained in manœuvering troops produces the practical man of military affairs who is needed to-day more than either the modern beau or ancient hero. If an efficient learner in military affairs has polite culture commensurate with his other qualities he will become a gentleman and a soldier. If a military student's refinement is beyond his skill, he will be made an object of imposition. If his culture is below his other powers, he may succeed in military affairs, but he is apt to make war more brutal than it needs to be at this stage of human progress. The function of physics in polite culture is now more easily set forth. It consists in restraining and strengthening so that more refinement becomes possible without the danger of enervation.

Our science begets a liking for knowing things that are so. It does this through the feelings by showing man his welfare at stake. Moreover, the sentiment produced is

neither spurious nor pedantic though it may be crude. One actuated by a spurious feeling of the type which I at present have in mind cares not so much for learning as for the emotions of learning. Who has not seen a student toiling daily to obtain not an education as he himself may fondly fancy, but to obtain the sensations that come with the getting of an education? That nice little woman so often seen in trains poring over foreign verbs and participles would never do anything with that language if she should get it; but, alas, she will never get it! Next year it will be another language or something else. She hears of the culture value of language and she feels the influence of this culture much as one hypnotized tastes what he is told to taste. She wears a dreamland halo and lives in a self-sanctified atmosphere. How much better she feels herself to be than her dancing and more frivolous sister! Her emotions are cheap, but they are spurious. And yet she is so nice and does so little harm we needs must like her.

Of the pedant there is no need to speak: we all know him and dread him. Speaking very generally we might say that literature, when its highest and most remote end becomes too little removed from the mere task of the moment, produces pedantry. Under the same conditions language begets spurious feeling; and science, boorishness.

Our sensations give to us a certain mental tone or modality, which modality, persisting, influences the feeling-tone received from succeeding sensations. This is also true in the higher intellectual realms. Each fact acquired leaves a mental taste, and these tastes taken together produce a liking in the individual which continues in the race. In the field of knowledge we have well-marked inclinations which form our intellectual temperament or disposition. Men collect facts of a certain order just as botanists collect plants. Some of us like or dislike truth just as others of us like or dislike poetry or music; that is, there is a truth-loving nature just as there is a poetic or musical nature. With different individuals the same piece of knowledge may not conform to the same end. Two students master the same discussion; the first feels satisfied on account of

the gentle flow of emotions accompanying the discovery that certain new facts by dint of toil have, at last, come to agree with previously acquired facts, although at first they did not appear to harmonize. The second student is elated because he feels himself to be so clever, because he can strut and pose, and because he sees a possibility of prevailing against some mortal of weaker clay. The emotions of the second are degrading and spurious.

This sickly imitation, however, is not the only cause of one's failing to receive the full emotional benefit of a piece of knowledge. Many facts fail to enter our temperament at all, or else fail to change our disposition in any due proportion to the time and labor spent in acquiring them. Much of moral instruction falls upon deaf wills, æsthetics frequently shows its beauties to blind emotions, and knowledge often seeks response from dumb intellects. The most beautiful poetic passages may fail to change one's attitude towards his neighbor. The higher refinements of oratory are to most people but "a thing apart," and even the noble lessons of example become ours, "as it were, in sort of limitation." The truths of philosophy are acquired by many a toiler who regards them as entirely external to the needs of everyday existence, and "such outward things dwell not in the desires."

If we consider the sentiments of the average pupil after he has pursued a course in physics, it will become apparent that the truths set forth do change, modify, or enter the temperament. This is, in part, due to the fact that the teachings do not take up the cudgel with egoism. If a student learns that water in boiling faster has no higher temperature, he has his feeling toward nature changed, and he cherishes no fond hope that he can break nature's laws as he does when he is about to eat a choice morsel of indigestible food. By virtue of the absence of this personal element in one's bearing toward velocity, ductility, elasticity, etc., he has his disposition somewhat changed by the understanding of these notions. Not entering the lists with egoism, however, our subject cannot conquer save by very indirect means. Natural philosophy commands no force of

moral suasion to cause us to despise and refrain from degrading egoism or disgusting gossip. It does, however, have an excellent opportunity to wean the young student from things concrete, presentative, and unclassified. It so skilfully trains the beginner in the spirit of independence that he is able to walk alone before he realizes that he is not bearing on the outstretched hand of the master. The danger here is the acquiring of a spirit of self-sufficiency and intolerance. This is to be overcome by cultivating the love of production.

In regard to the effect of science on our nature, let me observe that it cannot suddenly make us what we are not. It goes where men push it, and so long as men are arbitrary, conventional and intolerant, science must be more or less so. We are justified in making even a stronger assertion. Science is not much ahead of the people any more than government is much ahead of the body politic. If a great man or a great movement does stir the populace for a time in its attitude toward truth, the man, the movement and the emotion are constantly beset by the danger of going the way of the world. And this way of the world is too frequently in deep ruts and along narrow grooves.

This brings us to the distinction between real and conventional culture and to the realm of the intellect. There are those who have the audacity to imply and even the hardihood to assert that culture is the ability to see the beauties in literature. Such people know not even what *literary* culture is, much less do they know the meaning of culture in general. If we have our better parts well developed, shall we not be able to see the beautiful, the strong and the true? For the development of all of these parts training in special lines is, indeed, necessary; but in the course of instruction the teacher is apt to lay too much stress upon technic and mere conventionalities. In regarding the adornments made by man, we often lose sight of the simple beauties of nature.

Too often the enjoyment received from literary works is due to an acquired and somewhat unnatural taste. I have heard men read, re-read, and chuckle over Kipling, where

he says clever things indeed, but not hilarious ones, and I have been forced to the conclusion that there is a Kipling training. I suppose the abstract of such training received from the different authors would be regarded by many as literary culture. But this is mere polish and not real culture at all. The admiration for turns and tricks bears the same relation to the appreciation of the real worth of the author that the foam bears to the depth of the sea. I think it was Josh Billings who said that "it is better not to know so much than to know so much that ain't so." It is equally true that it is better not to admire so much than to admire so much that is not good; better not to laugh at so much than to be convulsed at what is really not so very funny; better not to go into ecstasies over so many beauties than to be so frequently enraptured by the distorted. This suggests the debt we owe to such men as Ibsen. Indeed, what might be styled the materialistic drama and the idealistic painting have much the same aim; that is, to proclaim the fact that the proper study of art is nature, not art.

But does our subject, which is concerned so largely with fact, possess any of the artificiality which causes one to lose either beauty or truth in the admiration of convention and fad? Alas, strange as it may seem, there is not a complete absence of foam on the sea of physics! Every decade does a number of experiments go the rounds of the schools and colleges, owing their popularity to so slight a cause as imitation, or perhaps even to such a scientific triviality as the fluctuation in values on the exchange of philosophic apparatus. Let one of the great universities introduce a set of experiments for reasons peculiarly its own, and many of the schools and colleges will sheep-like follow. An invention of Edison, accompanied by a bargain-lot of apparatus at König's or Zeise's, would be decidedly felt in the instruction for a few years to come. But are there no more formidable conventions than these? Electricity has had its fads. It is a god, a man, an animal, a fluid. All of these interpretations are more or less anthropomorphic. Stout, in speaking of faculty psychology, says: "It creates an appearance

of explanation without the reality, and in this way seriously retards the progress of science." The same may be said of the assumptions of any science; and, furthermore, it may be said that they tend to create an unnatural standard of excellence. I have known the ability of a scientist to be estimated by his power to talk ions. Classic science must have an Ionic dialect. But even further than this physics has its conventions. It is thought to be a science of simple fact and experimental proof, but it is also a science of interpretations, and these interpretations result too often in unsound theory, partial definitions and ill-formed concepts. Rapid discovery has caused us to give too little consideration to the relation among facts. Be this as it may, it is nevertheless true that when a theory is embraced it is not so likely to be treated as a classic work of art in natural as in some other branches of philosophy. Physicists, more than some other scientists, realize that the proper study of science is nature, not science. Furthermore, although physics does not seek the substance to the entire exclusion of the form, it tends to create a disgust for the meaner conventionalities of life. It is here that our science exerts one of its greatest influences on everyday existence.

In the qualitative element of a sensation physics is strong, but it is not so strong in the quantitative element, in so far as this element is an immediate intuitive estimation of the senses. Indeed, our science does not trust the senses to bear much quantitative testimony. One of its beauties consists in the reduction of sense quantity to sense quality. In this process of reduction space and time differences figure conspicuously. The quantity of the impression made on the end organ is not, therefore, intrusted with the quantitative element of the experiment. The eye may be trained to distinguish more minute differences of position, but there is very little training given in distinguishing the different intensities of light. Moreover, in the higher exactitude of measurements, much of the increased refinement is due to device. The senses in general, however, are so constantly used in investigating the properties of things that they, together with the power of

verbal expression, the interest and the attention in matters pertinent, must be disciplined.

The training of sense-perception is very efficient. The impressions are readily worked into higher mental products, but the reins are never given to simple dreamland fancy. In watching demonstrations or in experimenting, the pupil must relinquish any tendency to withdraw from the external world and to follow a train of his own ideas. Yet he must interpret his sensations in order to keep them consistent with the object to be attained. Thus do opposing elements exert on each other a wholesome restraint. Well-balanced and controlled intellectual activity is employed when the student stops observing to reflect on the work in order to determine whither the data lead, to correct error, or to imagine the conditions necessary to produce a desired result. The referring to externality at each conclusion leads to a culture which is difficult to obtain elsewhere.

In the formation of certain important concepts, and in the exercise of judgment in accepting and rejecting qualities in concept-building, physics is very, very strong. It is not so strong, however, in making these notions complete and definite, although it may render them adequate to its immediate purpose. For instance, it does not stop to discriminate between mass and matter before setting forth the methods of weighing. And although "space" becomes more explicit by virtue of the delicate space relations impressed by the use of the micrometer and similar instruments, our subject asks not whether space is an intuition, a postulate, or an abstract of experiences. In applying the concepts formed to contrivance and to experimentation, physics is strong, but it is weak in pointing out the bearing of these concepts on the complex affairs of life. Thus "time" is rendered more complete by virtue of its constant use in the second and parts of a second, but the value of time is not inculcated.

It would be impossible within the space-limit to discuss, even imperfectly, the concepts set forth by physics, for they are, indeed, numerous as well as they are important. Motion, momentum, force, energy, work, potential, inertia,

radiation, are but a powerful few culled hastily to represent dozens of giants and thousands of the lesser sort. It seems like imposing on credulity to ask one to believe that in courses in which physics is almost entirely neglected branches depending for their treatment on the concepts formed in the despised subject are quite thoroughly taught. Yet, as hard as this is to believe, it is none the less true. Why, in one of our neighboring cities the study of physics and chemistry has been so curtailed that it seems as if the good folk of the place expect to hear a mystic voice crying "great Nature is dead." Verily, there is something rotten in Denmark besides actors.

In explicit qualitative judgment physics is not so strong as her sister science, chemistry. Quantitatively, however, physics is strong, and, taken with chemistry, gives valuable training to the judgment.

Of formal syllogistic reasoning our subject makes very little use. In fact, one of its characteristics is its dependence upon immediate inference or upon the simple detection of similarity among products of judgment. Of the tricks and thrusts of the logician it steers clear; and, while disburdening its champions of the somewhat cumbersome armor of astute opposition in order to allow them to make quick and skilful attacks upon some of the prejudices of the day, it trains them not in the defensive art of disputation. The student of natural philosophy, however, is in no wise loath to try his growing powers in drawing conclusions from the truths he has been taught. Deduction is further drawn upon in the derivation and the application of formula.

If physics and its allied subjects do not stimulate induction, there then is no place within the walls of the school where this form of thinking is awakened. When complete inductions are not made in the laboratory, the fault is in the want of time and the lack of definite aim of the teacher. In work of investigation inductions are natural, healthful, and conservative.

For well-balanced intellectual activity there needs to be a cohesion and interdependence of concepts not only in the

construction of conscious acts of judgment and in the production of higher concepts, but also in the formation of a background to primary consciousness. When constituted by the facts of nature and their derivatives, this background keeps one from going greatly astray. The hypnotized subject loses his bearings, but the true scientist in his normal mood, by virtue of what he has thought and by virtue of what he has acquired, knows, as the Senator would say, "where he is at." But the contribution given to the proper cohesion of ideas by the science of to-day is somewhat lessened by convention; that is, the correspondence of the internal to the external would be greater in an ideal Emile than in one brought up on "science as she is taught." In spite of all, however, science tills well the soil into which the seeds of individual facts are sown. One of the main differences between a scientific man and a fact-monger consists in the interrelation among notions.

This cohesion of ideas or background of consciousness may well be called the Intellectual Resultant. If a body moves in conformity to the resultant of a number of forces, and still another force enter the scheme, the motion will be proportionately changed; but if the new force merely cross the path or if it detach a small part of the body, the motion of the main body will either not be changed at all, or changed in no due proportion to the magnitude of the new force. A parallelism can certainly be drawn between this and facts entering the mind, for the latter may either cross the path or act upon the intellectual motion or tendency. What temperament is to the feelings, what conscience is to the will, resultant is to the intellect.

Elementary physics, employing, as it does, sensation, perceptions and fundamental notions, must do much to modify our mental attitude, and a further study of the subject must give us a scientific bearing. It is true, however, that a fact may take part in the scientific without taking an equivalent part in that general resultant which bears on perfect living. For instance, a man may acquire the habit of suspending judgment in experimentation, and yet he may not hold in abeyance his opinion where he has heard a few trivial and

unproved facts in regard to his neighbor. Our bearing towards the everyday and smaller affairs of life gives evidence of our deeper natures, which natures find their training not only in gentle habit, but in the ways that stir the soul.

It might not be out of place here to say a few words in regard to suspended judgment. The cautious habit of waiting for data before coming to a decision can undoubtedly be trained by physical experimentation; but at present that acquired in the elementary work owes its principal debt to the lecture, the classroom, and the verbal part of laboratory instruction. It is by no means an easy task, in the time which we have at our disposal, to force the general student of physics into the attitude of investigation. The pupil knows when he is set to prove a fact, and, on such occasion, he will not play that he is not. In measuring distances his attitude of investigation is too apt to be spoiled by the idea of true length. This he frequently tries to determine, first, by asking questions, and second, by measuring. Have you not heard him ask of his teacher, "What is the distance?" and of his fellow, "What do you get it?" He should have it impressed upon his mind that the true length, according to his sensations and perceptions, is what he himself finds it to be, and that, in the case of primary experiences, to go on hearsay evidence is to cheat science and to impoverish the intellect. If, by better work, he is subsequently enabled to detect minuter differences, he should know that this improvement in discriminating power has made him a better being. Secondary knowledge, he should learn to see, depends for its interpretation upon experiences, and that the laboratory is the place to get some of these experiences and the place to learn how to get others. After all, things are to us what our sensations and perceptions determine them to be, and the world inside of the laboratory as well as outside of the laboratory is ultimately to the individual precisely what he gets it for himself.

The same statement cannot be made with regard to the advanced study of physics. In the laboratory the student investigates, and in the classroom he criticises. The knowl-

edge in this case, however, is not so likely to enter into the intellectual resultant and to modify the temperament in proportion to cost of acquisition as it is in the elementary study. The advanced concepts are too complex to be applied by any but a philosopher to the affairs of everyday existence. In fact, they sometimes fail of application to the work in hand. I have known a student in reproducing the explanation of an experiment to work out two mathematical expressions side by side and to neglect, at the end, a desired substitution, showing thereby that he has lost the very crowning point of the experiment. He may be instructed and re-instructed, drilled and re-drilled until he can end the story properly, but he will be as little cultured by the pretty trick as an animal is cultured by learning to walk on its hind legs. This student had reached his limit of complexity in notions of this order. I know of a very scholarly and original man in the province of the humanities who is unable to understand the higher mathematics. His marked success in his chosen field proves the more complex mathematical concepts to be beyond his needs. Of course, he might be better off if these notions formed part of his mental background, but as his mind is constructed he would waste time if he pored over the calculus. He is too wise to do this. If he had been stupid, pedantic and spurious, he might have gone on with his formulæ and fancied himself a mathematician, for he would not have been able to see that these higher concepts were taking small part in his intellectual make-up. He might even have fancied himself to be receiving important culture, because, forsooth, he lay awake all night, and in the early morning dozed off only to be haunted by dreams in which he saw the sign of integration chasing a trigonometric function around the garden, while off in one corner he beheld a mean little differential taking advantage of the order of things to tease the even root of a negative quantity just because the latter could not get out of its box.

There is a qualification that I must make here in order to explain my position. Our power of symbolism runs ahead of our power to give mechanical explanation. We letter our machine, add, multiply, subtract, divide and

substitute the letters, paying little attention to the mechanism until we apply the result. The mind no more follows definitely each move that the working of the formula means than it follows each rotation of the wheel. If we were to lay aside formulæ until we could understand all that they mean intuitively or mechanically, we should lay them aside until we could get along without them. But although we cannot always see clearly the relation of symbolism to phenomena, we should be able to understand the inter-relation of symbols.

So far we have considered the pupil. What truths of culture does the master teach? It seems too bad that the experimental scientist, with his highly trained powers of observation and judgment, does not take more interest in the affairs of general human progress! What a restraining influence he might exert on the popular passions! How excellently well he could veto those measures which threaten to become laws merely by virtue of their addressing themselves to spurious sentimentality! How much harder it would be to fool all of the people some of the time if scientists were ever awake and active in matters concerning public weal and woe! The love of truth and a feeling for the eternal fitness of things characterizes the scientist in his special toil; would it not be well for humanity if he could and would assert these qualities at the polls, and in public debate, and in other ways aid in subordinating popular impulse to social principle? But, alas! we cannot claim for a specialist the full culture of his subject! When one becomes involved in an investigation of a class of facts limited in range, he must become unduly developed in certain mental activities. This fault, if fault it be, is due to specialization of social function and not to any department of human knowledge. Each man has his limit of general mental growth, and, when this is reached, development must be along particular lines. The scientist of to-day can no more be blamed for not knowing the full bearing of his higher concepts on perfect living than can Thales be blamed for not realizing the practical possibilities of electricity. A scientist, on account of the nature of his work and on ac-

count of his peculiar temperament and intellectual make-up, needs to be somewhat released from the lower thoughts and lower needs of mankind. It is true that he must be a man as well as a specialist, and, as a man, he must have needs as well as duties; but for his highest work he must be stimulated by thoughts and emotions that refuse to be interpreted into terms of avarice, passion or sensuous enjoyment.

It would seem, on consideration of the hard names sometimes bestowed by one physicist upon another, that the subject did little for the spirit of free discussion. In as far as this is true it is due to a limited view caused by that high specialization which confines each laborer to a short and narrow field. Though this tendency to restrict one's view to his own kind of work is true of all subjects, it is especially true of natural science. Science is too indifferent to its standing in the community of subjects. Surely it is a grievous fault, and grievously hath science answered it. Its adherents have been so negative in educational matters, for instance, that they could almost be regarded as positive. Most of them bestow upon the consideration of correlation of subjects and of culture a magnanimous amount of icy neglect. By constantly measuring all men by their assumed and careless standards, they chill the enthusiasm of those who would act and enfeeble the voice of those who would speak. It is for this reason that science, with all its powers to train the mind, is so frequently regarded as the mere description of a trade, and that the laboratory is looked upon in much the same light as is the kitchen of a cooking school. If this is true of all science, what hope is there for the establishment of the disciplinary good of physics? Let me usurp the prerogative of an Irishman long enough to say that there are very few interested in the matter, and these care nothing whatever about it.

But it would be surely foolish to expect to establish the culture value of physics by a mental analysis of the physicist. It is proverbially difficult to teach the physician to heal himself, and it is still more difficult to teach him to live according to the rules of hygiene. Whatever be the

reason and whatever proverb be *dpropos*, it is still a fact that among professionals is a poor place to look for culture. We recognize this with regard to athletics, but not with regard to studies. The reason the professional athlete does not always make the best trainer is that he is apt to view his particular game or specialty as an end in itself. This difficulty may be, in a measure, obviated by careful co-ordination. And here is to be found a needed lesson for scientists; for the spirit of professionalism is impairing the grade of work and lowering the standing of the worker. When professionalism comes in at the door, culture goes out at the window.

In conclusion and in my own behalf let me add that I have tried to treat of physics in particular and of science in general as they exist in the curriculum of to-day. It would be impossible to describe our highest ideal and, at the same time, to maintain the dignity of philosophic language. As a department of human knowledge unclouded by fad, unstained by prejudice, untainted by any age or any locality, the importance of science is in no danger of being overrated. Out of doors, away from the influence of the workshop and the narrow sentiments of the laborers, who are hampered by restricted environment and exhausted by daily toil, the glory of science is like the glory of the noonday sun, too dazzling to look upon. If the bright sun of science could dispel the mists that at present disperse the rays and color the perceptions of truth there would be very different things to say about the culture value of physics.

TECHNICAL NOTES.

——According to an account in the *Scientific American*, the *air resistance to the rotation of a fly-wheel* may cause a considerable loss of energy. A 450 horse-power engine, direct connected to a generator, has a fly-wheel with channel-shaped arms. The tests were made by using the generator as a motor, driving the fly-wheel up to a normal speed. It required 13,300 watts to rotate the wheel and shaft, but by inclosing the arms in a sheet-iron casing the wheel was driven by an expenditure of 9,874 watts. The saving effected by use of the shield was 5·7 horse-power, or 1·2 per cent. of the power of the engine.

——Prof. A. G. Bell is quoted as predicting that *wireless telegraphy* will never supplant wires in land service on account of the interference of the

various stations. He considers the supremacy of the wireless method much more probable for transoceanic systems. Marconi reports having received messages on the Italian flagship "Carlo Alberto" which were sent from Cornwall across England and a portion of Denmark. The distances were from 850 to 1,400 miles. It is reported that a submarine torpedo boat at Cherbourg, France, fitted with a mast and wireless telegraph receiver, received distinct signals from a central station. The distance is not stated.

——Experiments made in the physical laboratory of Cornell University showed the production of 116 grains of *liquid air* by 1 horse-power in one hour. Only 2 per cent. of the energy expended is stored in the liquid air.

——Interest in the *Edison storage battery* is awakened anew by the practical tests which have been recently reported. A light runabout with twenty-one cells, weighing 332 pounds, made a run of 62 miles, climbing grades of 12 per cent., and at the end of the trip the battery was capable of driving the vehicle at 83 per cent. of normal speed. On a smooth and quite level road the carriage covered 85 miles on one battery charge. Five automobiles are being built to run 5,000 miles each on a test. It is expected to cover 100 miles on a charge.

——According to *Engineering News*, a special *trolley car for conveying fire-engines* is in use at Springfield, Mass. The engine is carried on a platform only 9½ inches above the top of the rail, mounted on a truck at each end. The front truck is detached and the front end of the platform lowered to the ground when the engine is to be loaded on the car. Platforms over each truck afford space for firemen and equipment. The length of the car over all is 30 feet 10½ inches, and its net weight is 14,000 pounds. The Springfield Fire Department has loaded an engine on one of these cars in two and one-quarter minutes from the time the car was in position to its being ready to start, and has unloaded an engine and attached the horses to it in one and one quarter minutes.

MAGNETIC DISTURBANCES IN THE UNITED STATES COINCIDENT WITH MT. PELEE'S ERUPTION.

A communication to *Science* by Superintendent O. H. Tittmann of the Coast and Geodetic Survey, refers to a magnetic disturbance which was noted at the United States magnetic observatories in Maryland and Kansas on the evening of May 8th. The disturbance occurred at practically the same instant at these two widely separated points, and the phenomenon appears to have been very nearly coincident with the eruption of Mt. Pelee. The following is quoted from Mr. Tittmann: "Purely mechanical vibrations caused by earthquakes are often recorded by delicately suspended magnetic needles. The disturbance of May 8th, however, was distinctly a magnetic and not a seismic one and hence was not recorded on seismographs. Until further information has been received from other observatories it cannot be determined definitely whether this magnetic disturbance was due to some cosmic cause or came within the earth's surface."

Mechanical and Engineering Section.

Stated Meeting, held Thursday, December 4, 1902.

Roman and Pre-Historic Remains in Central Germany.[1]

By Edwin Swift Balch.

In Central Germany, in the province of Hesse Nassau, there are numerous remains of the Romans and some even more interesting ones of the primitive Germans. German archæologists have given a good deal of attention to these remains during the last quarter of a century; and they have brought to light many facts in connection with the early history of man in Germany.[2] Passing over the times of feudalism, when the barons planted their strongholds on many a steep hill, and going back to the beginning of the Christian era, one finds that about the middle of the first century A.D., the Romans invaded the plains of Hesse Nassau, then inhabited by Germanic tribes, and established themselves south of the Taunus. The Romans soon found the need of protecting themselves in their new "sphere of influence" and they erected a line of fortifications from the Rhine to the Danube. The peasants formerly called this

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[1] Copyright, 1902, by Edwin Swift Balch.

[2] This paper is based partly on considerable personal observation and partly on the books, papers and verbal statements of the Königlich Baurat L. Jacobi, who has devoted his life to the exploration of these remains, and whose writings are a mine of information. I wish to express my indebtedness to this distinguished German archæologist.

Among the publications about Roman remains in Germany, are:

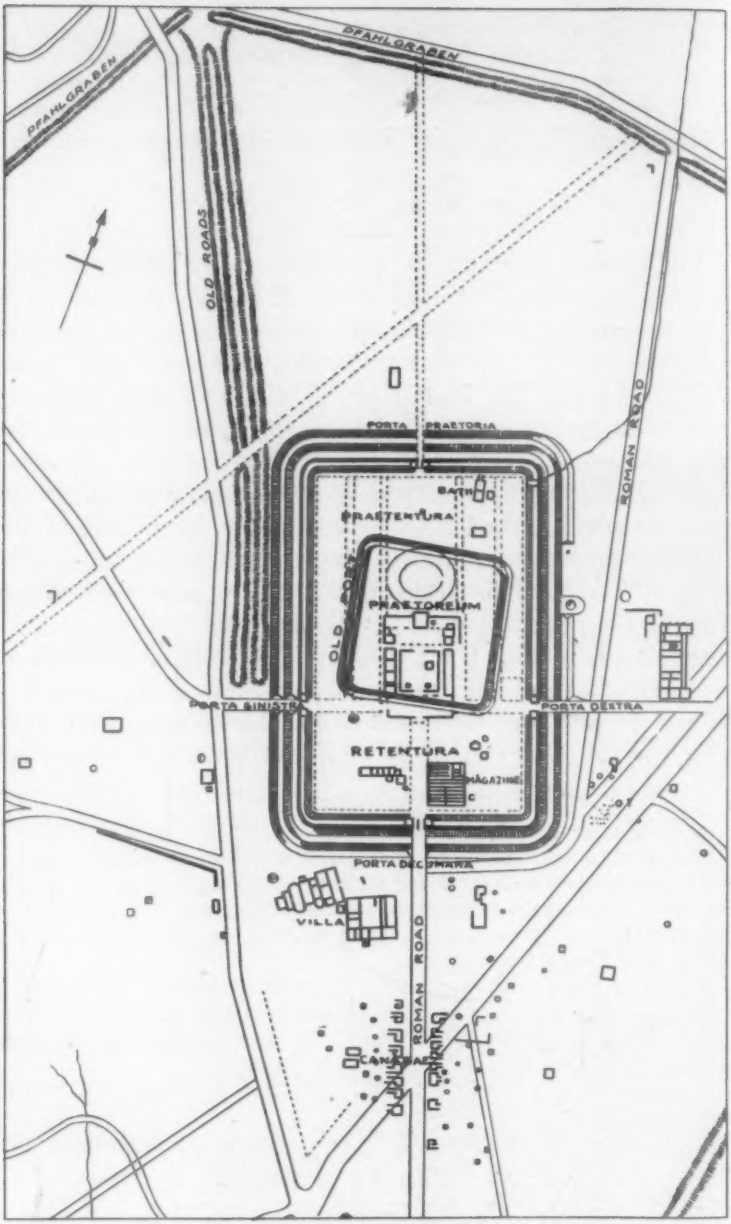
Jacobi, L. Baumeister: "Das Römerkastell Saalburg bei Homburg vor der Höhe," Homburg vor der Höhe, 1897. One volume, with maps and plates separate. This book includes an exhaustive bibliography.

Cohausen, A. von: "Der Römische Grenzwall in Deutschland," Wiesbaden, 1884.

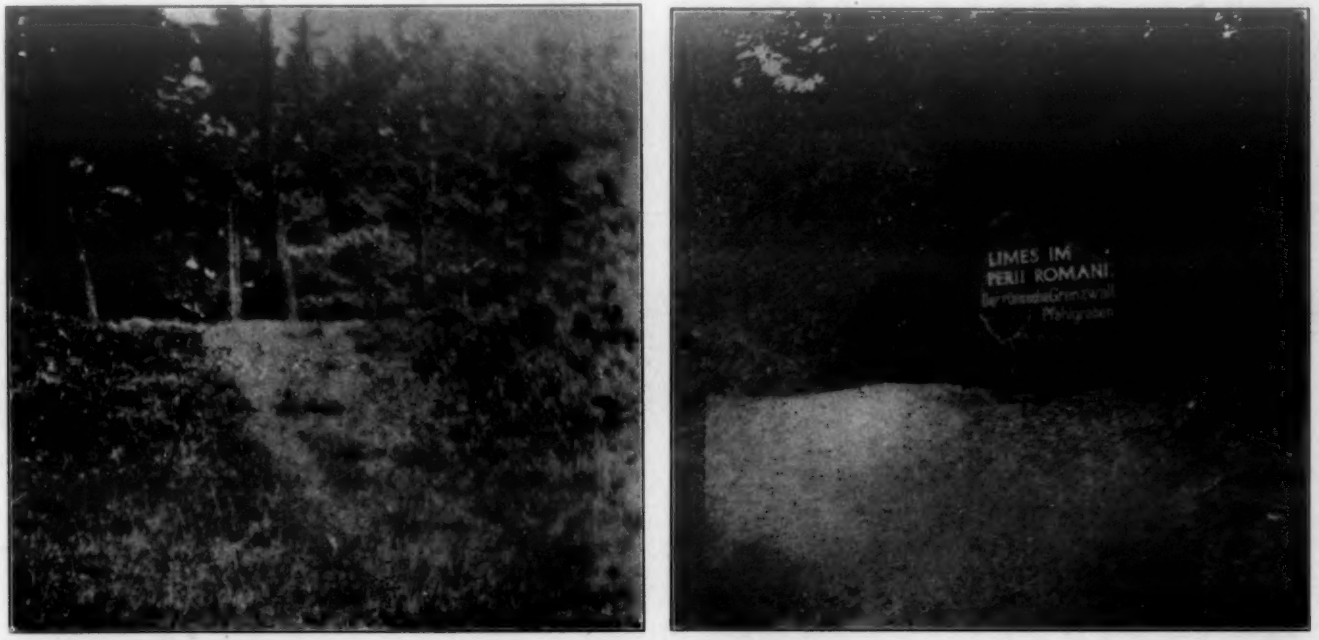
Cohausen, A. von, and Jacobi, L.: "Das Römerkastell Saalburg," Homburg vor der Höhe, Staudt & Supp, 1902. Guide Book.

Blümlein, Karl: "Die Saalburg," 1901.

Schulze, Dr. Ernst: "Römisches Soldatenleben in den Taunus Kastellen," Frankfurt A.M., H. Berchtold, 1898.



THE SAALBURG.
From the maps of Baurat L. Jacobi.



ON THE PFAHLGRABEN.
From photographs by Miss Nora Hamilton Coote.

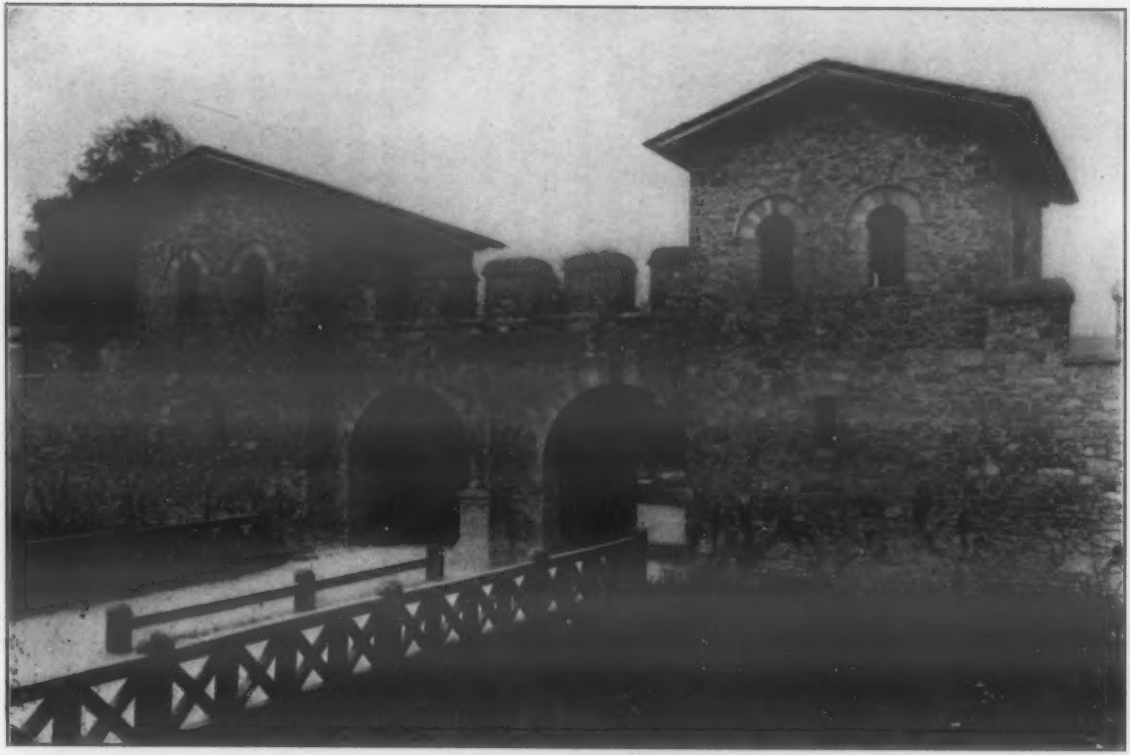
the Teufelsmauer, but it is now known as the Pfahlgraben, a name explained by some students as meaning a boundary, while others consider that it comes from the Latin *vallum*. The Pfahlgraben consisted of an earthen wall, and in some places of a wall and a ditch, and it can still be followed with ease throughout most of its length, especially in hilly and wooded places, where peasant farmers have had no opportunity of leveling it. The Pfahlgraben, which is about 542 kilometers long, begins near Hönningen on the Rhine, follows roughly the watershed of the Taunus Range, and after making a big curve northward, strikes the Main a little east of Frankfurt. It starts again at the southerly bend of the Main, goes some distance nearly south, and then almost due east a good distance to the Danube, which it reaches near Hienheim in the neighborhood of Regensburg. Although it is not known exactly when the Pfahlgraben was built, nor when it was abandoned, yet it is certain that it was constructed by the Romans, and that during portions of the first three centuries of the Christian era Roman soldiers stood on guard upon it. The Pfahlgraben, which from a political standpoint was not unlike the great Chinese Wall, was undoubtedly mainly intended to ward off the attacks of the unsubdued tribes of Northern and Eastern Germany, of whom the Chatten and the Allemannen were the most hostile; but it must also have been used as a tariff frontier, to levy tribute on any persons who crossed to the south. The reasons for locating a part of it north of the natural frontier of the Main are not self-evident; still it is noticeable that the mineral springs of Wiesbaden, Homburg and Nauheim are south of it, and the desire to profit by their beneficent waters may have been one of the causes which made the Romans enclose this country. For a time the barrier appears to have served its purpose, until, with the increasing degeneracy of the Roman empire, the sturdy northern barbaric element overwhelmed the enervated southern race.

Behind the Pfahlgraben, at comparatively short intervals, were about eighty large and small fortified camps and towers, where bodies of troops were held in garrison. The

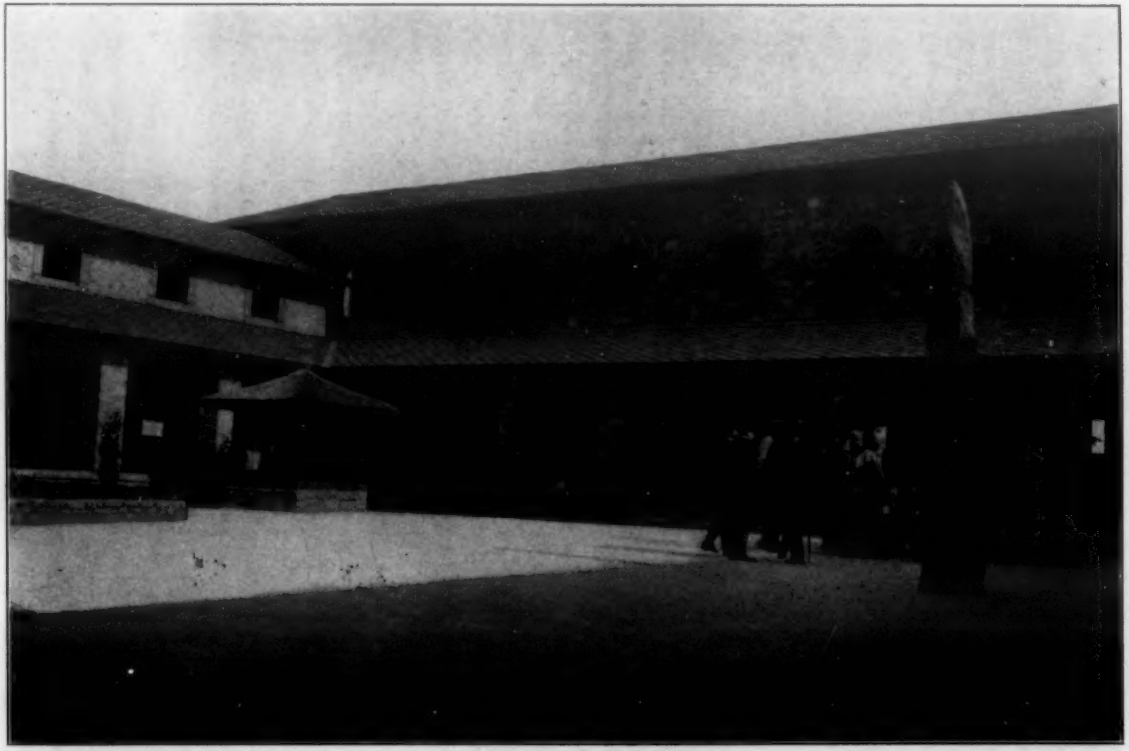
most important of these posts in the Taunus are known as the Kapersburg, the Zugmantel and the Saalburg. The latter, situated in one of the gaps of the Taunus, overlooks Bad Homburg, from which it can be reached in half an hour by trolley. It is now being restored entirely, but as late as 1872 it was little but a ruin in the forest, where only the foundations of fortifications and house walls and a few holes in the ground were visible.

There do not appear to be any written records from Roman times of the Pfahlgraben or the Saalburg; neither are there any legends connected with them, and the valuable help to history, therefore, occasionally afforded by myths, is in this case wanting. Our present knowledge is based practically on the remains of the foundations and on the relics found among them. But little as we know of the history of these old fortifications, yet there can be no doubt that the Latins and the Teutons once struggled for supremacy along them, and that the former were conquered and retired. And as one follows the lines of the Pfahlgraben and the ruined Kastells one cannot avoid the reflection that a great empire, advanced and civilized though it was, but with its members weakened physically and morally by centralization and the destruction of individualism, could not withstand the assaults of a ruder but stronger race, with its units undeteriorated by overcrowding and overgovernment.

The name Saalburg may come from the word *saal*, meaning hall, or *sal*, meaning boundary, but the origin of the name is still uncertain. The first writer known to use the name was the Homburger, Elias Neuhof, who mentions the Saalburg in a letter in 1747, and who wrote a short account of it in 1777. He saw it still in a state of tolerable repair, although it had served as a quarry of ready-cut blocks of stone to the neighboring peasants, and although many of its stones had been carried off for building the castle and the Lutheran Church at Homburg in the seventeenth and eighteenth centuries. It was only in 1818 that the taking away of the stone was stopped, and not until 1853 that the first diggings were undertaken by the antiquarian, F. G. Habel. In 1870, Colonel A. von Cohausen was entrusted with



THE PORTA DECUMANA, SAALBURG.



THE ATRIUM, SAALBURG.
The Emperor of Germany has Baurat Jacobi at his right hand.

the excavations and repairs at the Saalburg, and in 1871, Königlich Baurat L. Jacobi joined him, and under his guidance the work is still carried on. The Homburg "Saalburg-Verein" furnished some of the money, the Emperors William I and Frederick III likewise assisted with funds, and the present sovereign in 1897 ordered the reconstruction of the central building. The rejuvenating of the Saalburg is progressing slowly but steadily, and each year sees a certain amount of reconstruction carried out, as well as a certain number of archæological finds. Every care is taken to insure the utmost possible accuracy in reconstruction. Roman camps similar in character have been examined in other parts of the world, for instance, near Fréjus and Cannes in France and near Lambæsis in Algeria, and these have been followed in many details. Roman authors, like Cæsar and Tacitus, have been studied diligently for every passage which might bear on the subject, and it is safe to assume that the new Saalburg will closely resemble the original. Certain persons take exception to the rebuilding of the Saalburg, but it may be well to suggest in rebuttal that no ruin would give the same impression of reality as the restored building, and, moreover, that there are some seventy-nine other camps of the same kind in a state of ruin.

The Saalburg was a fortress, but one practically constructed on the lines of a Roman military encampment, and it may perhaps better be designated as a permanent fortified military camp than as a fort. There is little doubt that, in the order of time, there were three permanent camps at the Saalburg. The first was probably an earthwork, and was much the smallest. The second, it is believed, was of wood and was probably destroyed by fire, possibly after a fight. Various remains have been discovered leading to these conclusions. The third camp was built almost on the lines of the second and was surrounded by a stone wall whose outside dimensions were 221·45 meters in length by 147·18 meters in breadth; that is, the sides had a relation of 2 to 3 The wall was about 2·50 meters in height and was crenelated, to allow the legionaries to hurl their *pilums* or throw-

ing spears through the openings. On the outside it was surrounded by a double, probably dry ditch, while on the inside it was banked up with earth, forming a platform for the soldiers to stand on. On each side was a gate: to the south the Porta Decumana, to the north the Porta Prætoria, to the east the Porta Dextra and to the west the Porta Sinistra. The Porta Decumana had a double entrance and the other three only one each, and each of these gates was flanked by two small towers. The northern and southern gates were in the middle of their respective sides, while the eastern and western ones, through which it is believed the troops made *sorties*, were at one-third the distance from the southern end and faced exactly the doors of the main building.

The southern wall and half of the eastern wall, and the Porta Decumana and the Porta Dextra are already rebuilt as well as the Prætorium within. Over the outside of the Porta Decumana is an inscription: "Guilelmus II Frederici III Filius Guilelmi Magni Nepos Anno Regni XV in memorian et honorem parentum castellum limitis Saalburgense restituit." In front of the gate is a statue of green bronze with some gilt decorations: it is by a German sculptor, I. Götz, and is inscribed: "Imperatori Romanorum Tito Aelio Hadriano Antonino Augusto Pio Guilelmus II Imperator Germanorum."

The interior of the Saalburg is an almost level rectangular space which slopes gently towards the north and in the center of which is the Prætorium. The southern end is spoken of as the Retentura, the northern end as the Prætentura, and the eastern and western parts as the Latera Prætorii.

The Retentura, which was farthest from the enemy, was the place for the commissariat and quartermasters' departments. In the eastern half are the remains of the Horreum or provision house, as is demonstrated by the cross walls still remaining and the hooks for hanging meat found there. In the western half of the Retentura are the remains of what is called the Quæstorium, which may have been the officers' quarters.

FOUNDATIONS OF THE VILLA, SAALBURG.
With the remains of the heating apparatus.

The Prætentura, at the northern end nearest the enemy, was the quarter of the soldiers, who lived there either in tents or in wooden huts. Here, somewhat sunk in the ground, is a small circular ring, which was at first supposed to be an amphitheatre; but as many horseshoes were found there, it seems most probable that it was a riding ring. At the northeastern end of the Prætentura are the remains of a bath which dates back probably to the earliest earthwork camp and which does not appear to have been used at the latest period. This bath consisted of two main parts. One with a seat in it was a cold-water bath. The other was heated from underneath and was subdivided into two portions, of which one was a warm-water bath and the other probably a hot-air bath.

The Prætorium, which is 60 meters long and 40 meters wide, is in the position where the tent of the commander was placed in a flying Roman camp. It is now almost restored and is to be used as a museum for the various finds. The southern end is a big wooden-roofed hall with stone walls in which are two stories of windows of which the upper ones are the biggest. It is supposed that during bad weather the soldiers were drilled and practised in throwing the pilum and vaulting on a wooden horse in this hall. Adjoining this to the north is the Atrium, a courtyard open to the sky and surrounded by a wooden-roofed piazza. In the Atrium are two wells, one with a wooden, the other with a thatched roof, and the remains of a little building of uncertain date and use, but which was perhaps a Sacellum for the first or second camp. On the east and west sides of the Atrium, beyond the piazza, are long narrow chambers and to the north is another smaller court, beyond which are several more rooms. The middle one of these was probably the latest Sacellum, where the military insignia and the statues of the gods and emperors were kept.

Immediately around the Saalburg there are many ruins. To the east and west the foundations of many small houses show that there must have been something of a settlement. To the south are the remains of many Canabæ, *i. e.*, houses of suttlers and camp followers and also drinking shops,

probably not unlike our saloons. Immediately before the western front of the south wall are the foundations of the so-called "villa," which was possibly the house of the commander in peace times, or which may have been an officers' club, and where at the proper season wild strawberries now grow in abundance. There appears to have been a bath here, or at least there is a heating apparatus under one room. From the Porta Decumana a road led south to Heddernheim in the valley of the Nidda, and on both sides of this, some 300 meters from the gate, was a burying ground, where some 350 graves have been discovered. The dead were cremated and the ashes placed in an urn, together with small jugs, pieces of—often false—money and other small articles.

The water supply depended on wells, of which fifty-eight have been found up to date. Eight of these are in the camp. Almost every small house had its own well. The oldest have wooden sides, while the later ones have walls of stone without mortar. The dirty water was carried away by drains or canals, some of which still act.

The heating system was ingenious. A shallow cellar was dug and a number of low brick pillars erected. These supported a floor of terra cotta tiles and concrete. Outside of the house was a sort of oven, which had an opening into the cellar, and the cellar was also connected with the outer air by terra cotta pipes placed against the inside of the walls and opening at the roof or within the room. A wood-fire was built in the oven and the hot air went into the cellar and enough of it rose through the terra cotta pipes to keep up a slow draught. The floor and the walls were gradually heated up and the room was doubtless kept warm for a rather long time.

Many articles have been dug up at the Saalburg, principally under the ruins or in the wells. Some of these are primarily of historic importance. Such for instance are numerous terra cotta slabs bearing inscriptions like the following: "C O H. II. R A E T" (Cohort II. of the Rhetii); "C O H. III. V I N D" (Cohort III of the Vindelicii). These prove that some of the troops stationed along the Pfahlgraben were German auxiliaries, and it may well be

that, tired with the overbearing Romans, when the last struggle occurred, they fraternized with their oncoming relatives and took their share in ending the Roman domination in a turmoil of blood and fire.

Many coins have been dug up, and these give a tolerably accurate means of estimating the duration of the Roman sojourn. Twenty-two coins date from 268 to 30 B.C., a few belong to the reigns of the earlier emperors, but it is in the reign of Vespasian (69–79 A.D.) that they first become numerous, and it was doubtless about that time that the Saalburg was started. There are many coins with the effigies of Domitian (81–96); Trajan (98–117); Hadrian (117–138); Antoninus Pius (138–161); Marcus Aurelius (161–180); Septimus Severus (194-211); Heliagabalus (218–222); Severus Alexander (222-235); and Gordianus III (238–244). The latest ones are of the reigns of Valerian (253–259) and Claudius Gothicus (268–270). It is probably not far out of the way to assume that Roman control of the Taunus came to an end about that time after lasting some two centuries.

Some of the finds are chiefly of archæological and ethnological interest. Such for instance is the pottery in the shape of amphoras, jars, etc., of which much has been dug up; but especially noteworthy are the broken panes of glass of which many pieces were found in the "villa," for they show that in northern climes the Romans used glass windows. The panes range from a light green to a dark-blue color, and they were about 40 centimeters by 40 centimeters.

Among the iron relics the horseshoes are most note worthy. A number have been found in the riding ring, and they show that the Romans, in Germany at least, used them. Shoes for mules and oxen are also not uncommon. The spurs were cleverly made, as the shank did not point straight from the middle of the heel but curved somewhat outward: there was thus no danger of the rider accidentally striking his horse, for he had to turn his toes out and bring his heels well in to spur him. In this implement the Romans were ahead of any other people. Few weapons have turned up, probably because they would be most jealously cared

for from their great value to friend and foe in such a wild region. Tools, on the contrary, are rather numerous, and the hammers, saws, axes, nails—but no screws—are much like those still in use in Germany. A number of the tools are for left-handed workmen. One small garden pick is so exactly like a Swiss ice-axe, that one might almost assert that it was an ice-axe. The works of art are unimportant, consisting principally of a few little bronze statuettes.

Over a hundred and fifty articles of leather have been taken out of the wells, where the mud seems to have acted as an air-tight preserver. The most important are one leather jacket and a number of sandals and shoes. No entire pair of these has turned up, but only worn out single specimens, some shaped like an undeformed foot, but many ending in a point in the middle of the toes.

Of the animal bones discovered, all belong to now existing species, except a few of the aurochs (*bos urus*) and the swamp-boar (Sumpschwein, *sus scrofa palustris*). It is not wonderful that stag and roedeer remains are plentiful, for these animals may be seen constantly in the vicinity of the Saalburg, and the gates have to be barred at night to prevent their coming in to feed. Indeed, Herr Georg Baer of Homburg tells me that some years ago he saw stags fighting in the Saalburg, while the hinds were looking on.

Leaving the Saalburg and following for about 3 kilometers eastward the Pfahlgraben, which there consists of an earthen rampart with a beveled edge and a ditch, one reaches the foundations of the small square fort, now known as the Lochmühle, which was doubtless the post of the garrison which kept guard in the *thalweg* of the Köppern Thal. Continuing along the Pfahlgraben and passing the foundation-wall of a small Roman tower, after about 6 kilometers more through beautiful woods, one arrives at the Kapersburg.

The Kapersburg resembles the Saalburg, but it is not more than half the size, and it is still even more untouched than was the Saalburg thirty years ago. It is surrounded by a ruined wall in which there are four gates. There are the foundations of a prætorium and several other buildings

within, and so far three wells have been discovered. A bath or villa situated between the Kapersburg and the Pfahlgraben is now being ransacked. This has the remains of heating apparatus, and coins, bronze ornaments, pots, etc., are often turned up. Herr Jacobi told me that, as at the Saalburg, remains of three sets of forts in the order of time exist at the Kapersburg. The walls can be followed only with difficulty, and the whole place is hard to examine, as it is full of pitfalls and it is covered with a dense growth of thorny brushwood, in which my companion, Professor George F. Barker, and I once started a roedeer.

Even more interesting and much less known than the Roman remains, however, are those of the early native races. A certain number of their architectural efforts have come down to us, and these are a mute comment in showing the danger these peoples were constantly in from their brother savages. These earliest constructions are the walls —generally of a fairly circular form and hence now called *ringvälle*—which undoubtedly were refuge forts, to which the native inhabitants fled for shelter with their cattle at the approach of an enemy. These ringwalls are generally on hill tops, and, as a rule, are partly surrounded by a ditch. There is no trace of mortar—which was doubtless unknown to the native builders—among the stones of these ringwalls, and it is believed that they were held together by layers of wooden beams, and that it is owing to the rotting away of the latter that the stones have sunk together into long heaps. According to Cæsar, the Gauls built forts with the stones of the walls bound together by layers of wood, and a bass-relief on the Trojan column shows similar forts as in existence among the Dacians. This gives a clue to the date of these German ringwalls. Although they may have been used in post-Roman times, yet they were probably in use at the arrival of the Romans. It would seem likely, therefore, that they were erected by a Celtic or Germanic people in a bronze age, but it is not impossible that they originated long before with a people in a Neolithic stage of development.

Half an hour's walk from the Saalburg is one of these

ringwalls, the Gickelsburg, which is so hidden in the forest that it is hard to find. It is 220 meters by 165 meters in dimension, and the rather small stones have sunk together into a long, oval heap. The finest of these ringwalls in Central Germany, however, is the one on the Altkönig, above Falkenstein, which is in full sight of Homburg and easily accessible. I examined it in company of Professor George F. Barker. This fort has a double line of walls, both in good preservation, which entirely surround the summit plateau of the mountain, enclosing a space several hectares in extent. Each wall, at present, must be some 8 or 10 meters in breadth by about 3 meters in height, so that the original dimensions may be estimated at some 5 or 6 meters in breadth, by the same in height. The stones average in size from perhaps the bulk of an orange to that of a large watermelon, although there are some few bigger ones. They are evidently the mountain stone brought together and piled up, and Professor Barker thought they were all a quartzose sandstone. We saw no traces of wood or vitrification, which latter occurrence, probably caused by fire, is found occasionally in the somewhat similar "vitrified forts" of Scotland. At the eastern base of the Altkönig is the Altenhöfe, another single-walled ringwall, smaller and less perfect than the one on top.

A certain number of the implements of the early Germans have also been obtained in the Taunus and in the plains of Hesse Nassau. In 1880, near the Ferdinands platz in Bad Homburg, a great find of bronze implements and weapons was made. Among these are axes or celts, lance-heads, some plaques or bosses for shields, bracelets, sickles, etc. They may date to 600 or 800 B.C. It is possible that some of them were cast in the neighborhood of Homburg itself, but it is probable that most of them were made in Bologna, Italy, and that they reached Germany through regular trading. They would seem to show that the Germanic peoples, for some centuries before the Roman invasion, were in a bronze age.

Neolithic implements also are found in Hesse Nassau. While the smooth-stone axes and tools are not numerous,

yet enough have been dug up to make certain the fact that some thousands of years before the Christian era, savage Neolithic tribes shared the still virgin forests with the aurochs, the bear and the lynx, and that they slowly carried forward the evolution of man in Central Germany. When the use of these instruments began and when it stopped is not known, but in July, 1902, while digging up the earth at the Porta Sinistra of the Saalburg, two small smooth-stone implements were found in the same layer with Roman remains, and this is a noteworthy piece of evidence that the use of smooth-stone implements *may* have continued until the beginning of the Christian era.

A few chipped rough-stone arrow-heads have also been found in Hesse Nassau. The specimens look exactly like North American Indian arrow-heads. They are probably Paleoliths, but the evidence is still meager about the earliest peoples of Central Germany.

Notes and Comments.

TWO YEARS IN ARGENTINE AS CONSULTING ENGINEER OF NATIONAL PUBLIC WORKS.*

By Elmer Lawrence Corthell.

The lecture was introduced by a brief statement in reference to the selection of Mr. Corthell, by the United States Government, and recommended by it to the Argentine Government, to act as its Consulting Engineer for a definite period.

Mr. Corthell was a delegate of the Argentine Government at the International Navigation Congress, at Düsseldorf, last summer, and when called upon to respond for that Government, he opened his remarks by a brief comparison of some of the interesting features common to both countries. This comparison is given in the lecture, and in order to fully appreciate the location of Argentine, some of the most important geographical features.

The lecturer then makes an interesting comparison between the Mississippi River and the Rio de la Plata and its tributaries, in reference to the geologic and hydraulic causes which, in ancient times, changed the course and the volumes of both rivers, and, by great sedimentary deposits, made the underwater areas suitable for the habitation of man. Areas of drainage and volumes

* Synopsis of a lecture delivered in the Hall of the Y. M. C. A., Philadelphia, Friday, November 12, 1902.

of discharge, under ancient conditions and under present conditions, are briefly given.

The above features—geographic, topographic and hydrographic—are illustrated by colored charts. The more important ports on the great rivers—the Paraná and Uruguay—are mentioned, and some interesting features in reference to the velocity of currents, volumes of discharge, etc., are stated. The present and proposed depths in the two rivers and the commercial features are briefly given. The great Rio de la Plata is specially treated.

After giving the hydraulic conditions of Argentine, there is a brief description and illustrations of the Andes, and the effect of the mountainous condition of the country upon civilization is briefly described.

Having reviewed the physical conditions, a résumé of the history of Argentine is given, including a brief account of the aborigines in this and other parts of South America, with a very brief review of American ethnology. The struggles of the Colonies of Spain to become independent are described, and the influence exerted by the United States during the conflict. The three great heroes of American independence — Washington, Bolivar and San Martin – are compared, and the campaigns and patriotism of the great hero of Argentine, General San Martin, are treated at some length.

Following the history of Argentine, the present Argentine is described—its area, its climate, its productions, and, generally, its agricultural, industrial and commercial features; its telephones, telegraphs, railways, the cable lines which reach it, and, in fact, all conditions of interest.

Following the general description of Argentine is a description of the city of Buenos Ayres, its streets, buildings, water and sewerage works, its extensive port-works, and many details of interest. All of which are illustrated by lantern slides.

Following the general characteristics of the country and city of Buenos Ayres, there is given a brief résumé of the ocean commerce, which has done so much since the discovery of the country in developing its resources. Several important projects for giving additional facilities, both at Buenos Ayres and elsewhere, are described and illustrated.

During the descriptions above stated, there are given comparisons with other cities of the world, including those of the United States, as to population, mortality, growth and other features.

The National Government has recently completed a very important dry dock at one of the more southerly ports of the country, and this is described and illustrated.

The lecture closes by some lantern slides of interesting features of the city of Buenos Ayres, and a brief statement of the reasons which have prompted the lecturer to give this lecture in the United States.

The lecture will be published in full later on. W. H. W.

GAS-ENGINE RESEARCH IN GERMANY.

The Institution of Civil Engineers publishes the following abstract of a report by Eugene Meyer issued in the *Zeitschrift des Vereines deutscher Ingenieure:*

This is the first installment of the results of experiments of gas-engines carried out at the Institute for Technical Physics at the George Augustus University in Göttingen. The engine employed for the research work is a 10 horse-power Deutz motor. Both lighting and power-gas are to be used. A description is given of the engine, power gas plant and the apparatus to be used for measuring the gas, cooling water etc., and the degree of accuracy to be expected with the measurements.

The first questions investigated were concerning the effects of varying amounts of piston lubrication and the temperatures of the cylinder walls. The lubrication was begun with one drop every 40 seconds, for which the mechanical efficiency was 0·706, and the amount of gas used per brake horse-power per hour 823 liters (29 cubic feet), and per indicated horse-power per hour 582 liters (20½ cubic feet). The lubrication was gradually increased until the oil was running in almost a continuous stream. The mechanical efficiency had risen to 0·79, the gas used per brake horse-power per hour had fallen to 648 liters (23·2 cubic feet), and per indicated horse-power per hour to 512 liters (18·3 cubic feet). The load on the engine was practically the same throughout.

The great decrease in the amount of gas used as the supply of lubricant was increased is accounted for by Meyer on the supposition that some of the oil was vaporized in the cylinder and burned along with the gas. More elaborate experiments were made with the same result. In further experiments the temperature of the cylinder walls was varied from 16° C. to 70° C., while the oil supply was very liberal. In both cases the heat value of the gas supplied was 2412 W.E. (9648 B.T.U.) per indicated horse-power per hour. From this it seems possible that even at comparatively low temperatures lubricating oil may be burned and contribute to the work done on the piston. The accuracy obtainable with the ordinary indicators was specially investigated, and also the methods of calibrating the springs. The temperature of an indicator may of course vary, and it was found in one case that the scale of the spring altered by 4 per cent. when the temperature was changed from ordinary room temperature to about 90° C. The dynamical theory of the indicator is applied to a few actual cases, and a graphic method is given by which the use of a Fourier series to represent the relation between pressure and time is avoided. The inertia of the parts is found to have little effect. Friction and inaccuracy of fitting in the indicator motion are the most important factors in distorting diagrams from their true shape. The indicated power of a gas-engine cannot be determined with perfect exactness, and, while in many cases an accuracy of 1 per cent. may be obtained, in others the errors may be as much as 2 or 3 per cent.

Book Notices.

The Mineral Industry, its statistics, technology of, and trade with the United States and other countries to the end of 1901. Founded by the late Rich'd. P. Rothwell. Edited by Joseph Strouthers, Ph.D. Vol. x, supplementary volumes i to ix. New York and London: *The Engineering and Mining Journal* (Inc.). 1902. Large 8vo, xxx + 982 pp. (Price, $5 in the United States; $7 for foreign countries in the postal union.)

The annual volume of "The Mineral Industry," of which the tenth has lately issued from the press, is so useful a compendium of the progress of the mining and metallurgical arts that it has come to be almost indispensable to those having to do with them professionally or otherwise.

The gathering of the vast amount of facts and figures contained in these year-books by experts conversant with each special branch of the subject must commend itself to the reader as the only satisfactory method of obtaining data that can be relied upon to be approximately accurate.

The work reflects much credit upon the industry and ability of its editor and his collaborators. W.

Cattle-Feeding with sugar-beets, molasses and sugar-beet residuum. By Lewis S. Ware. Illustrated. Large 8vo, xxiii, + 389 pp. Philadelphia Book Company, 15 South Ninth Street, 1902. (Price, $2.50 net.)

The author is widely known as one of the most persistent pioneers in this country in advocating the domestication of the beet-sugar industry. The present work treats of one of the numerous collateral industries associated with its succcessful development, and deals more especially with the important economic sale which the utilization of certain residual products of the beet-sugar manufacture is made to play in European countries, where the sugar-beet residuum, pulp and molasses are used most successfully for cattle-feeding.

The subject is elaborately treated, and the author's conclusions are supported by an impressive statement of facts and figures. The work should prove of much value to all agriculturists who have the intelligence to know the value of applying scientific methods in their practice.

The book is elaborately indexed. W.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, December 17, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 17, 1902.

President JOHN BIRKINBINE in the chair.

Present, 260 members and visitors.

Admitted to membership since last month, 12.

The following nominations were made for officers, managers and committeemen, to be voted for at the annual election to be held on the day of the annual meeting, Wednesday, January 21, 1903, viz.:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	THEO. D. RAND.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	W. O. GRIGGS.

For *Managers* (to serve three years).

CYRUS BORGNER, JARWOOD LUKENS,
JAMES CHRISTIE, LAWRENCE T. PAUL,
F. L. GARRISON, HORACE PETTIT,
H. W. JAYNE, OTTO C. WOLF.

(To serve for two years.)

CHARLES LONGSTRETH, WALTON CLARK,
LOUIS E. LEVY.

(To serve for one year.)

WALTER WOOD.

For *Members of the Committee on Science and the Arts* (to serve three years).

H. F. COLVIN, C. C. HEYL, LUCIEN E. PICOLET,
THOMAS P. CONARD, H. R. HEYL, CHAS. E. RONALDSON,
GEO. S. CULLEN, GEO. A. HOADLEY, CLAYTON W. PIKE,
CHARLES DAY, H. F. KELLER, SAMUEL P. SADTLER,
ARTHUR FALKENAU, LOUIS E. LEVY, HENRY LEFFMANN,
J. M. HARTMAN, TINIUS OLSEN, W. N. JENNINGS,
ERNEST M. WHITE, RICH'D L. HUMPHREY.

(To serve for two years.)

KERN DODGE, WERNER KAUFFMANN,
E. GOLDSMITH, JESSE PAWLING, JR.,
FRANK ROSELLE.

(To serve for one year.)

ROBERT H. BRADBURY, J. W. REDPATH,
WM. O. GRIGGS, CHAS. A. RUTTER,
URBANE C. WANNER.

Mr. Chas. M. Taylor, Jr., gave an account of his invention of an improved and simplified method of making butter by what he termed the absorption process, and exhibited the process in operation and specimens of the product.

Dr. J. Merritt Matthews supplemented Mr. Taylor by some explanatory remarks on the scientific features of the process.

Prof. Eugene C. Foster followed with a communication describing an improved process of producing oxygen on the commercial scale from liquid air as operated by the Columbia Liquid Air Company, of Washington. D. C. The speaker illustrated the operation of the process experimentally.

On motion, both communications were referred to the Committee on Science and the Arts. Adjourned.

WM. H. WAHL, *Secretary.*

[*Abstract of proceedings of the stated meeting held Wednesday, September 17, 1902.*]

DISCUSSION:—THE SUPPRESSION OF THE LOCAL SMOKE NUISANCE.

Remarks of MR. JOHN M. HARTMAN.

Can the smoke nuisance be abolished? No.

Can it be abated? Yes.

To what extent? Say, 80 per cent.

Bituminous or soft coal has come to stay. With each successive strike in the anthracite districts its use has become more general; and the manufacturer finding it better adapted to his use, and cheaper, will continue the use of it. Under these circumstances, it now becomes the duty of the city government to establish laws regulating its use, as has been found necessary in Pittsburg, Chicago, St. Louis, Cleveland and elsewhere.

It is the proclivity of Americans to love walking on the edge of a precipice. In running their boilers they work them up to the full extent, often beyond it, with an occasional explosion. In thus running we have a smoky chimney when using soft coal, as the volatile matter evolved from it passes off largely unconsumed. If the boiler owners would add extra coking surfaces to their boilers, retaining their grates, they could consume the gas (and their boiler also if they were careless). To this want of boiler capacity, add bad firing, with poor draught, and we have stated the case of the present smoke nuisance in Philadelphia. Metallurgical furnaces, of course, contribute their quota.

This extra coking surface will help to do more than normal work with a boiler, without smoke, though at the expense of the coal-bin. The first operation in burning soft coal is the driving off the volatile hydrocarbons. These gases and vapors must be burned quickly so as to utilize their heating effect at once, and the remaining part of the coal must be promptly changed into coke. The second operation is to burn the coke, the heat from which in its turn heats the gases and assists in developing their full heating power. One pound of these gases develops more heat than a pound of anthracite. The burning of these gases increases the intensity of the heat in the furnace and perfect combustion ensues, no smoke being visible at the chimney-top. The first operation, therefore, is a coking process, and should be kept separate from the second operation, which is a burning process. No fresh coal should be placed on the burning coals of the firing surface, as it lowers its temperature and causes smoke.

There are three types of furnaces that cause the smoke nuisance:

First, stationary boilers.

Second, locomotive, marine and portable boilers.

Third, metallurgical furnaces.

STATIONARY BOILERS.—All our stationary boilers are set with grates close to the boilers, as anthracite coal burns with a short flame and no smoke. Bituminous coal burns with a long flame, requiring the grate to be placed much farther from the boiler in order to give the gases time to burn before reaching the cold surface of the boiler; otherwise the gases are chilled and are not completely burned, giving a smoky chimney-top.

The first question that suggests itself to the practical mind is, what can be done quickly and cheaply to burn soft coal under such boilers with less smoke? The answer is: "Lower the grate-bars and put openings in the side-walls to admit air over the surface of the fire." The admission of the air should be through a valve controlled by the fireman. On throwing coal over the fire he opens the valve wide, and closes it as soon as the gas is burned off. Otherwise he lets in air when it is not wanted, and a chilling effect is produced, causing a waste of fuel. Some smoke, but not much, will appear at the chimney when fresh coal is thrown on the fire or when the fireman rakes the fire, but it will not be above the No. 2 scale of Ringelman.

If owners and users of boiler furnaces adapted for anthracite are willing to expend a little more money, the following method will enable them to obtain practically smokeless combustion with soft coal.

Retain the usual firing surface or grate, and removing the fire front from the underside of the boiler down to the top of the lowered grate bars or firing surface, then place at the end of it an inclined surface the full height and width of the furnace and allow the coal to slide down this broad surface. The coal is thus exposed to the radiant heat of the furnace, which drives off the gas constantly and before it reaches the firing surface. This prevents cold fuel from coming in contact with the firing surface to lower its temperature and interfere with the proper burning of the gas. As the firing surface needs replenishing from time to time, the fireman should push the coked coal from the bottom of the incline over the firing surface, keeping the bed uniform in thickness and the fire hot. As the coked coal is pushed forward the coal above slides down the incline to fill up the vacancy. A large hopper should be placed above the incline to feed the coal to the incline by gravity as fast as it is used. Pushing back the furnace top to get the incline enlarges the furnace and allows more time to consume the gas.

The factor of time in the furnace to burn the gas properly is important; the more time allowed, the better the combustion. The widening of the incline allows a thin sheet of coal to slide down, giving the radiant furnace heat a better chance to penetrate through it and drive off the gas. Some mechanical stokers have the incline but do not provide a large grate surface at the bottom of the incline.

These suggestions apply only to the present hand-fired furnaces as a cheap means of helping the smoke nuisance.

Locomotives, Portable and Steamer Boilers.—If one observes a locomotive being fired, he will usually notice that after the coal is thrown on the fire a thick bronze-black smoke appears at the top of the stack, which in a few minutes clears up. The coal soon cokes together, which interferes with the draught, the fireman with his scraper breaks up the coked crust, causing a thick black smoke. There had been too much coal thrown on the fire at one time and the heat coked the surface of the coal before the gas was expelled from the interior of the coal. The sudden change from the cold air to the hot fire has done this. If the coal had been gradually heated up, nearly all the gas would have escaped before the final coking and the high heat of the furnace would have been maintained.

Why do some locomotive firemen go along with little smoke, while others leave a heavy black cloud a mile or two long? If one can do it, why not

all? The first man is firing with his brains, using coal little and often, doing his work well. The second man is firing with his muscle; the results we know and feel. He does not work up all the nice points of his duty and does his work badly. Large locomotive boilers with only one fire-door, not large at that, place the fireman at a great disadvantage to keep an even fire. He is compelled to heap the coal in places, and after the smoke passes off enough to see the bed of fire, he must take the scraper and try to level off the coke. This brings into play the hidden surfaces of the coal not yet having lost their gas, and smoke appears at once at the chimney-top.

The inclined coking surface can be applied to any boiler by an intelligent mechanic; it is simply an enlargement of the patent of James Watt in 1785, called coking on the dead plate. By making this incline in two parts, hinged at each side, it is quickly opened and the whole furnace readily got at for repairs or examination. Other arrangements can be made with a little mechanical skill, but simplicity and durability must be adhered to.

The New York Central Railroad has adopted a system of gas-burning after testing it under adverse circumstances, in which they found a saving of 12 per cent. of fuel, the locomotive doing that much more work. The smoke was trifling and fell below No. 2 scale.

A fire-brick arch suspended above the grate surface of locomotive furnaces has been of great help in burning the gas. It has had more general use than any other improvement.

At present all locomotives are forced beyond their capacity owing to the great rush in freight and travel and the shortage of locomotives.

METALLURGICAL FURNACES.—Under this head come coal puddling and heating furnaces for iron, gas open-hearth, gas-heating furnaces and forges.

In the boiler furnace the sole object is to burn the fuel to carbonic acid and get the highest heat out of it. In metallurgical furnaces fired with coal the gas can be burned to its highest heat until the metal begins to soften, when the gas must be burned to one volume of carbonic acid and one volume of carbonic oxide, called a neutral flame, to prevent the metal being burned or oxidized. During the time of the neutral flame smoke shows at the chimney-top. Carelessness at this juncture will burn the iron. If this gas is burned with plenty of air after it leaves the neck of the puddling furnace, it can be used to generate steam and leave no smoke escape worthy of mention. Arrangements for this purpose have been perfected and when properly handled are working well at large establishments in this city. Furnaces fired with gas have regenerators to heat the gas and the air, thereby obtaining higher heat and greater economy of fuel. These furnaces will never smoke unless they are driven beyond their capacity or under certain conditions, when to save their metal they use an excess of gas, causing smoke to appear at the chimney-top for a short time.

Metallurgical furnaces should have high chimneys, and their escaping gas should not show higher than No. 3 of the smoke scale at short intervals. Escaping gas from the gas furnaces goes off at about 600°, which sends it well up into the air through a high chimney and is dissipated before it can seriously annoy the public.

Every establishment visited by the speaker had one common remark to make, viz.: "So much depends on the fireman attending to his duties prop-

erly." No matter whether hand-firing or mechanical stoker is used, the same complaint is made. This shows the necessity of having a corps of firemen who, after trial and passing a satisfactory examination, should be licensed by the city. We license engineers; why not license the men who hold a position far more dangerous than the engineer? A few minutes of low water and an explosion may take place which may destroy life and wreck the premises. They should be men of good qualifications and properly protected by rules that would be just for all. They should be held responsible for excessive smoke and not annoy the owner with things the fireman is delegated to do by the city. Firemen using anthracite can fix up their fires and rest twenty minutes to a half hour before looking at their fires again. With soft coal attention is required every five minutes or less if it is required to burn the coal economically and without smoke. It is constant attention that is required, and to shirk this labor the fireman lets his fire burn down low, then shovels the furnace full of coal, causing the black-smoke nuisance, and a waste of fuel.

Locomotive firemen find it easier to sit in the cab and play with the locomotive bell than to be steadily firing and get good results. The engineer is on constant duty from the time the train starts to the end of his trip; why not the fireman also?

Mechanical stokers are used in many large establishments with good results and little smoke. In small establishments they have not come into use for lack of room and cost. They should be used where practicable, but even with mechanical stokers, it is found that an experienced man must run them.

The "Committee on the Smoke Nuisance," appointed by the Councils of Philadelphia, want to recommend the use of just laws for the benefit of the city, and to cause as little trouble and expense to citizens as possible. They desire to meet parties interested and will give them a careful, courteous hearing.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, December 3, 1902.*)

MR. THOS. P. CONARD in the chair.

The following reports were adopted:

(No. 2206.) *Turrett Lathe.*—Julius Wilhelm v. Pillter, Leipzig, Germany.

ABSTRACT.—A supplementary report introducing some further information respecting the comparative merits of the v. Pillter machine and American lathes of the same class. The Edward Longstreth Medal of Merit is awarded to the inventor. [*Sub-Committee.*—Hugo Bilgram, Chairman; Arthur Falkenau, J. Logan Fitts.]

(No. 2235.) *Hydraulic Ram.*—Chas. C. Wentworth, Roanoke, Va.

ABSTRACT.—The invention is not a patented one. The features of novelty, for which particular merit is claimed, consist in the arrangement of pipe and

check-valves for maintaining the supply of air in the air-chamber, and the combination with the waste-valve of a spring buffer to prevent the shock of closing. The details would be unintelligible without the aid of illustrations.

The report awards the Edward Longstreth Medal of Merit to applicant for "the ingenuity displayed in the analysis of the problem, the efficient and simple manner of reducing shock in the waste-valve, and the careful attention to the details of construction and installation. [*Sub-Committee.*—Lucien E. Picolet, Chairman; Chas. E. Ronaldson.]

(No. 2242.) *Electrolytic Method of Making Caustic Alkali and Bleaching Powder.*—Chas. E. Acker, Niagara Falls, N. Y.

This report is reserved for publication in full. The award of the Elliott-Cresson Medal is made to the inventor. [*Sub-Committee.*—Jos. W. Richards, Chairman; Chas. J. Reed, Sam'l P. Sadtler.]

(No. 2251.) *Bridging-Bell for Telephones.*—John J. Carty, New York.

ABSTRACT.—This invention is the subject of letters-patent No. 449,106, March 31, 1891, granted to applicant, and describes a multiple-circuit arrangement for telephone party lines, including at each station a permanent bridge in which is seated a bell magnet with a high coefficient of self-induction and of marked impedance. There are also two other bridges, normally open, and closed only when the station is in use. The telephone circuit, normally open, is closed in multiple arc with its own bell magnet, and, of course, with all others in the line, when in use. The generator-call circuit, normally open when used, forms a second bridge or cross connection between the wires in parallel circuit with the bridge circuit of its own bell and those of all others in the line. In operation, the tendency of the call-circuit to short-circuit is counteracted by using a bell magnet of high self-induction and impedance.

This not only prevents short-circuiting, but also effects more even current distribution through the bell magnets of the entire system. By means of the numerous windings of the bell magnets, the small fraction of the call-current passing exerts a marked magnifying effect on the cores and a spirited working of the call-signal.

The investigators find, after an examination of the prior state of the art, that "Mr. Carty's work consisted in adapting the bridging-bell to party lines by increasing the resistance of the bell-circuit to make it opaque to the transmission of voice-currents. * * * and that in the adaptation of well-known electrical engineering principles to a particular and difficult branch of telephony, it shows professional skill of high order." Since the use of this method has contributed largely to the expansion of party-line telephony, the award of the Edward Longstreth Medal of Merit is made to the inventor. [*Sub-Committee.*—L. F. Rondinella, Chairman; E. A. Scott.]

The following reports passed first reading:

(No. 2229.) *Hydrocarbon Burner.*—C. Francis Jenkins, Washington, D. C.

(No. 2248.) *Photo-polychrome Printing Process.*—Henri J. Burger, Zürich, Switzerland.

(No. 2265.) *Window Structure.*—Theo. H. Schmitz, Philadelphia.

(An advisory report.)

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

ELECTRICAL SECTION.

Stated Meeting, held March 20, 1902.

Electrical Measuring Instruments.

BY CARYL D. HASKINS.

In selecting for the title of my paper so vague a term as "Electrical Measuring Instruments," I am quite aware that almost anything might be expected of me. Webster, I believe, defines the term "instrument" as a tool or implement. The selection of the word instrument, with its very vague literal meaning, for use in connection with a very concrete and definite class of electrical apparatus, is regrettable, but doubtless now beyond correction.

In electrical engineering practice the term "instrument" has come to mean very definitely all of that large group of devices which serve to indicate at any time the definite value in the desired unit of some electrical phenomenon. In short, the generic term "instrument" has been narrowed almost to a specific term, from sheer necessity resulting